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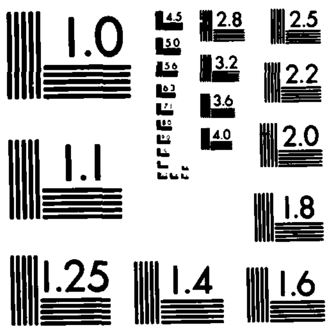

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2

A SYSTEM DYNAMICS POLICY ANALYSIS
MODEL OF THE AIR FORCE
AIRCRAFT MODIFICATION
SYSTEM

Michael Y. Fong, GS-12
Charles F. Hiser, Captain, USAF

LSSR 91-82

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The Air Force aircraft modification system has a complex and dynamic nature which continually challenges management's ability to develop effective policy to support decision-making. With the invaluable assistance of key managers within the modification process, a policy model of the process has been developed using the system dynamics concept. The formal and informal system structure and policies which currently exist for the aircraft modification process are addressed in the research. The purpose of the dynamic policy model is to provide a tool to assist Air Force strategic managers in understanding the complex nature of the system and to identify the most important areas that are sensitive to changes in either structure or policy. The model, thus, provides a device for policy development.

LSSR 91-82

A SYSTEM DYNAMICS POLICY ANALYSIS MODEL OF THE AIR FORCE AIRCRAFT MODIFICATION SYSTEM

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

Michael Y. Fong, BS
GS-12

Charles F. Hiser, BA
Captain, USAF

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and

Mr. Michael Y. Fong

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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PROBLEM DEFINITION

Introduction

The Air Force Business Research Management Center at Wright-Patterson Air Force Base has determined that there is a need to improve the management of the Air Force Aircraft Modification System. It reports in its research topics catalog:

> Substantial acquisition funds are spent in modifying existing systems rather than procuring new ones, but little research has been carried out in providing solutions to the many problems of modification programs . . .
>
> Improving modification management will entail an examination of organization, priority-ranking process, funding, budgetary, programming linkage, and business practices. The objective of this research will be to provide some answers to the problems of modification management [1:5].

A recent study of the Air Force aircraft modification process directed this question to the management community, "What is believed to be the most critical issue preventing more effective modification management today [1:3-15]?" The responses of 132 key managers actively involved in the modification process were categorized as shown in Figure 1-1. Forty-two percent believe the modification process is too slow, cumbersome or complex. An additional six percent believe effective management is hampered by a lack of understanding of the modification process itself.

Rank	Issue	Percentage of Responses
1	Modification Process too Slow, Cumbersome or Complex	42
2	AFSC/AFLC Split Management	19
3	Lack of Weapon System Master Modification Planning	12
4	Lack of Reliability and Maintainability Aspects or No Lifetime Developer Accountability	8
5	Lack of Understanding of Modification Process	6
6	Inadequate Requirements Definition Process	5
7	Other	8
	Total	100

Fig. 1-1 Ranking of Critical Modification Management Issues

More specifically, some of the more typical comments researchers (6:B16-B17) received in response to their interviews and mailed questionnaires were:

1. There are multiple, overlapping and poorly defined layers of responsibility. There is no clear and simple description of process and various responsibilities.

2. There are too many funding delays and approval levels. The budget process is overcomplicated.

3. Complex funding is controlled by different agencies, requiring different inputs for approval--some one-year money, some three-year money.

4. Complex modifications become obsolete by the time they are fielded.

5. Milestones and cost estimates are required to be too precise. If even a slight error or change occurs on CCB forms, coordination must be accomplished again, when, in fact, the figures and dates may be only rough estimates.

6. There are delays in engineering evaluations and CCB approvals.

7. There are overcautious decision-makers who check and recheck.

8. There is a serious lack of understanding of formal guidance and the modification process--need a training program across all organizations involved in the modification process.

Those familiar with the aircraft modification process must surely agree with the ARINC report when it concludes that the present USAF modification process is not very efficient, and contains some fundamental problems in the policy decisional/structural area (6:3-19).

Problem Statement

It is the goal of the Air Force modification program to correct deficiencies or improve capabilities of existing systems. If current technology is to be translated through aircraft modification into deployed military capability in a more timely manner, then it is crucial that the efficiency and effectiveness of the Air Force modification management process be studied and possible improvements recommended.

Problem Analysis

In a complex and everchanging aircraft modification organization, what tools will key modification managers use to aid them in the analysis of, and the decisions between, various alternative solutions to problems involving organizational policy and structure?

A manager's decision is generally based upon a combination of factors such as knowledge, experience and, once in a while, even their own intuition. Some theorize the manager as basing his decisions upon a mental image of the system structure and its processes (24:285). Whatever his method, the dynamic and complex nature of the modification process makes it extremely difficult for a manager to plan, predict and evaluate the impact of his decisions.

Before a manager can make appropriate decisions, he must first have some understanding of organizational structure and operation. This understanding may be accomplished in several ways. For example, schematic diagrams, such as the organizational chart, may aid in understanding the lines of communication or authority in an organization, while flow charts and graphs and various types of models can be utilized to help understand an organization's operation. Today, through the use of computers, managers have a tool by which they can simulate the workings of an organization, and evaluate the impact of a decision or new policy without actually having to implement it.

Research Question

How can a modification process model be designed to capture and analyze the many varied and complex policies of the modification system?

Research Objectives

The general objectives of this research are to develop a conceptual understanding of the complex, dynamic nature of the modification process and, subsequently, develop a computerized policy model which reflects the structure of this process.

Specific objectives of this research include:

1. Identify the structure of the modification process.

2. Isolate the interactions and influence of the components and variables within the system.

3. Describe the decision structure that determines the information, funding, and material flows within the system.

4. Construct a mathematical model which represents the components, relationships, information flows, and decisional policies of the system.

5. Develop a computerized model which can be used for policy analysis and development.

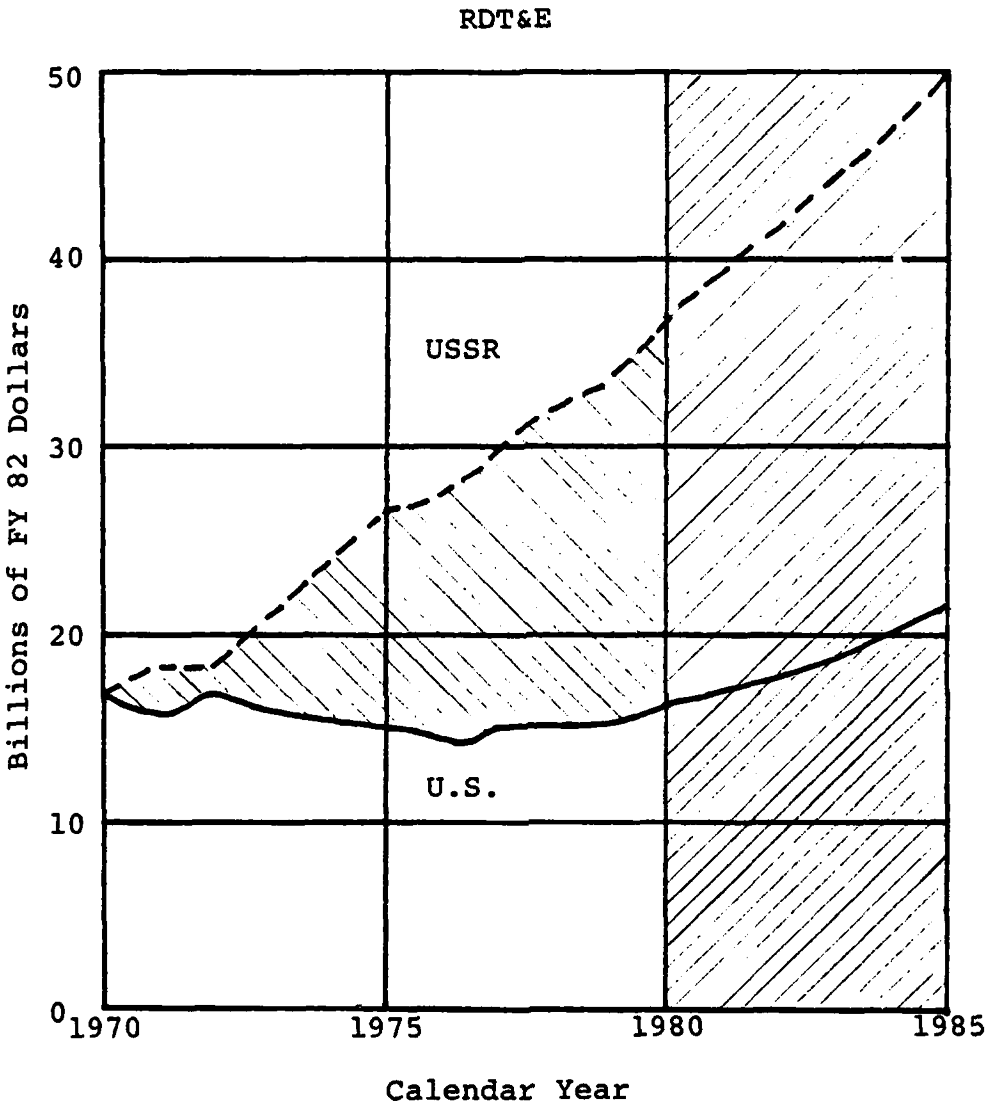
6. Verify and validate that the model represents the structure and decision-making process within the modification process.

7. Identify areas of sensitivity or critical issues in modification policy.

8. Suggest changes, if required, in the management structure of the modification process.

Background and Purpose of the Thesis

Throughout the military superiority duel between the Soviet Union and the United States, it has been U.S. strategy to offset Soviet advantage in numbers ". . . by applying technology to equip our forces with weapons that out-perform their Soviet counterparts [22:1-7]." However, how long can this strategy remain effective against an adversary that is outspending us by a 2:1 margin in the area of research, development, test and evaluation (RDT&E) as depicted in Figure 1-2 (22:107).



NOTE: Included non-DOD-funded defense programs

Fig 1-2. U.S./USSR Military RDT&E Expenditures [26:1]

It is the consensus of the Department of Defense (DOD), the Central Intelligence Agency (CIA), Defense Intelligence Agency (DIA), and the National Security Agency (NSA), as shown in Figure 1-3, that the system technology level has already shifted significantly to favor the USSR in eighteen of thirty deployed military systems. When looking at the future, it is the feeling of the Joint Chiefs of Staff that:

> The growth in tangible Soviet military strength is even greater than the difference in U.S. and Soviet defense spending suggests, for the USSR devotes a larger portion of its large defense effort to investment in research; development; test and evaluation; procurement; and military construction--all of which contribute to increase future military capabilities [15:8].

If we are to counter the continued Soviet build-up with our strategy of superior technology, then we must have real financial growth in defense investment, real cooperation between ourselves and our allies, and an improvement in productivity from our industrial base (22:1-8). President Carter began, and President Reagan has continued, financial support to the defense industry. A program to establish a more effective military alliance with our allies through co-production of military hardware has been undertaken, and action has been initiated to increase the productivity of our industrial base.

One of the more important actions taken to raise the productivity of our industrial base, is to increase the

DEPLOYED SYSTEM	U.S. SUPERIOR	U.S.-USSR EQUAL	USSR SUPERIOR
Strategic			
ICBM		X	
SSBN/SLBM	X →**		
Bomber	X →		
SAMs			X
Ballistic Missile Defense			X
Anti-satellite			X
Tactical			
Land Forces			
SAMs (including Naval)		X	
Tanks			← X
Artillery		X	
Infantry Combat Vehicles			X
Anti-tank Guided Missiles		X	
Attack Helicopters		X →	
Chemical Warfare			X
Theater Ballistic Missiles		X →	
Air Forces			
Fighter/Attack Aircraft	X →		
Air-to-Air Missiles	X		
PGM	X		
Air Lift	X		
Naval Forces			
SSNs		X	
Anti-Submarine Warfare	X →		
Sea-based Air	X →		
Surface Combatants		X	
Cruise Missile		X	
Mine Warfare			X
Amphibious Assault	X →		
C^3I			
Communications	X →		
Command and Control		X	
Electronic Countermeasure		↖X	
Surveillance and Reconnaissance	X →		
Early Warning	X →		

*These are comparisons of system technololgy level only, and are not necessarily a measure of effectiveness. The comparisons are not dependent on scenario, tactics, quantity, training or other operational factors. Systems farther than 1 year from IOC are not considered.

**The arrows denote that the relative technology level is changing significantly in the direction indicated.

11-18-80-19

Fig 1-3. Relative U.S./USSR Technology Level in Deployed Military Systems efficiency and effectiveness of our management and decision-making capability. In large, complex organizations such as the United States Air Force, efficient and effective management decisions are more likely to emanate from managers who understand the operation of their own organizations as well as their organization's interaction with and impact on surrounding organizations. A manager who has such a perspective is said to be taking a "systems view" of his operation (24:5-35).

Several approaches to systems thinking may be taken: cybernetics, operations research and system dynamics to name just a few. In 1961, Jay W. Forrester developed a method of systems analysis for managers called "Industrial Dynamics." He stated that it was a ". . . quantitative and experimental approach for relating organizational structure and corporate policy to industrial growth and stability [10:13]." Since then, the name has given way to "system dynamics," and the method, modified and improved upon, can be used in conjunction with several quantitative computer languages, for modeling and studying the behavior of large, complex systems (18:150).

This research will combine the system dynamics approach and the computer simulation language of DYNAMO to build a model of the aircraft modification process. The objective is for this model to be viewed as a tool, the use of which, will provide the modification manager a means to better understand and analyze the process with which he is involved. A more detailed description of the actual research methodology will be given in Chapter III.

Summary

It will be the purpose of this thesis, using the system dynamics approach, to develop a model of the Air Force's aircraft modification process, in the hope that this model will enable managers within the process to gain a systems perspective of their operation. Further, once this perspective has been attained, to then utilize the model in identifying governing policies, perhaps the changing of which may lead to improved performance of the real modification system.

Plan of Thesis Presentation

Chapter I has defined the problem and established the purpose of this thesis. Chapter II will present a literature review of models, simulation and the modification management process. Chapter III discusses research methodology. Chapter IV will discuss the formulation of the model, while Chapter V presents the thesis summary, conclusion and recommendation for further study.

CHAPTER II

MODELS, SIMULATION AND THE MODIFICATION MANAGEMENT PROCESS

Introduction

To achieve the research objectives of this study, it will be necessary to understand both the aircraft modification management process itself, and the tools and methodology used to analyze it. Chapter III will present the methodology to be used, while topics discussed in this chapter include: policy rules and decision-making in a large organization; modeling and the simulation process; modification management policies and procedures; and, finally, the magnitude of the Class IV and V modification process in terms of man-hours and dollars.

Policy Rules and Decision-Making in a Large Organization

Since one of the objectives of this study is to present a policy model of the modification process, a logical first step is to define the term policy as it is used in this report. We will accept Webster's New Collegiate Dictionary's definition of policy as ". . . a definite course or method of action selected from among alternatives and in light of given conditions to guide and determine present and future decisions [29:882]."

Jay W. Forrester puts the terms policy, decision-making and management into perspective when he says,

> Management is the process of converting information into action. The conversion process we call decision-making. Decision-making is, in turn, controlled by various explicit and implicit policies of behavior. As used here, a 'policy' is a rule that states how the day-by-day operating decisions are made. 'Decisions' are the actions taken at any particular time and are a result of applying the policy rules to the particular conditions that prevail at the moment [10:93].

The success of a manager can often be traced to the results of his decisions. Good decisions require optimal use of available information. Generally, more information is available than a manager can assimilate, and his decisions become based upon information which he considers to be of highest priority. Once he has decided the importance of the information available, other decisions he must make are: What is to be done with the information once it is received? How are desired objectives created from the information available? How quickly or slowly are these objectives converted to actions (10:93)?

The dynamic behavior of a large complex system is the result of the interaction between many variables within the system. It has been pointed out by Forrester, however, that ". . . men are not good calculators of the dynamic behavior of complicated systems [10:99]." He goes on to state

> The number of variables that they can in fact properly relate to one another is very limited. The intuitive judgment of even a skilled investigator is quite unreliable in anticipating the dynamic behavior

> of a simple information-feedback system of perhaps five of six variables. This is true even when the complete structure and all the parameters of the system are fully known to him [10:99].

If it is difficult for a manager to anticipate the behavior of a simple information-feedback system, what about predicting the impact of various policy changes in a large, complex, multi-informational feedback system such as the aircraft modification process?

To aid the manager in his prediction of policy changes in large complex organizations, the system dynamics approach was developed. System dynamics models have been applied successfully to diverse areas. Forrester listed several applications of the concept to various real-world situations such as corporate policy, social forces affecting drug addiction, and growth and development of urban areas (12:13).

With the aid of a system dynamics policy model of the aircraft modification process, the manager will be able to analyze and evaluate the impact of policy decisions before they are actually implemented. This may allow the manager to eliminate enough decisional and structural problems, to significantly improve the efficiency of the modification process.

Modeling and the Simulation Process

A model is a ". . . representation of an object, system or idea in some form other than that of the entity itself [25:4]." A model's purpose is to help us explain, understand or improve the object or system being modeled, by providing us with a systematic, explicit and efficient way of logically focusing our knowledge, judgment and intuition (25:4). A model's purpose might be broken down even further into whether it is a descriptive model, used for explaining and understanding, a prescriptive model, used for predicting and duplicating behavior characteristics, or a combination of both. A model, if it is to be useful as a tool and aid to top managers in manipulating the policy and structure of an organization, must generally be prescriptive in purpose. Robert Shannon states

> . . . a prescriptive model useful in design is almost always descriptive of the entity being modeled, but a descriptive model is not necessarily useful for design purposes. Perhaps this is one reason why economic models (which have tended to be descriptive) have had little impact upon manipulating economic systems and little use as tools to aid top management, whereas operations research models have had an acknowledged significant impact in these areas [25:7]

Simulation may be defined as experimentation with a model of a real system (25:10). Some important factors to consider when simulating a system are: establish boundaries--deciding what is and what is not a part of the system to be studied; reduce the real system to a logical flow diagram or static model--designing the model around the questions to be answered rather than imitating the real system exactly; and remembering that there are few vital parts and many trivial parts and that significant events only occur when the vital parts are affected (25:26).

Direct experimentation on the real system, although yielding the best and most accurate outputs or results, does have several disadvantages. It could disrupt operations. It may be very difficult to maintain the same operating conditions for each replication or run of the experiment. In studying the real system, it may be too time-consuming and costly to obtain a large enough sample size to be statistically significant. It may not be possible to explore many types of alternatives in real-life experimentation. And, finally, if people are an integral part of the system, the so-called "Hawthorne effect" may affect the results--the fact that people are being observed may modify their behavior (4:503-504).

Since direct experimentation may not always be practical, simulation may not only be a useful alternative, but may be preferable to real-system experimentation in terms of the information to be gained. For example, owing to our ability to measure and control the real system's organizational structure and policies, through our model, we may learn more about the system's internal interactions than we could through the manipulation of the real-world system itself (25:7).

J. L. McKenney states additional advantages of modeling in the following quotation:

> . . . (the manager) gained new insights into his operation. He designed the model to test a variety of alternatives so he could evaluate these new insights. In essence, he was using the model to amplify his manipulative skill by explicitly identifying all important ramifications of a given change . . . he turned to the

model as an evaluator of his new insights. It is conjectured the model design will never be stabilized, but continue to develop in response to the manager's new understanding [19:43].

Simulation, then, allows the researcher to play with a model of the system. It assists him in understanding and gaining a feel for the problem and, thus, aids him in the process of innovation (25:11-12). However, before simulation can be used, a basic knowledge and understanding of the system's policies and procedures must be acquired.

Aircraft Modification Management: Policies and Procedures

Policies and procedures governing various aspects of the modification process can be found in a number of Air Force publications. A list of the primary publications found beneficial in constructing a policy model of the Air Force modification process can be found in Appendix D.

As stated in Chapter I, the purpose of the Air Force modification program is to correct deficiencies or improve capabilities in existing systems.

There are basically five categories of Air Force modifications. Table 2 of Air Force Regulation 57-4, lists and explains the five classes, and the approving authority for each. Table 2 has been reproduced and can be found in Appendix A. Class I modifications involve a temporary removal, installation, or change to, equipment for a special mission or purpose. Class II modifications are also temporary in nature, but are accomplished to support research and development, design changes, and test evaluation programs. Class III modifications are permanent changes made to correct deficiencies found during production, Program Management Responsibility Transfer (PMRT) from AFSC to AFLC has not occurred. Class IV modifications are like Class III, in that they are permanent modifications performed to provide needed logistical support, improve equipment reliability or maintainability, or correct material deficiencies that endanger personnel and equipment. However, unlike Class III, they are accomplished on equipment and systems for which PMRT from AFSC to AFLC has occurred. Class V modifications provide a new or improved operational capability or remove an existing capability that is no longer needed.

Normally it is the Air Force Logistics Command (AFLC), through its five Air Logistics Centers (ALCs), that is responsible for proposing, processing and approving Class IV modifications for weapon systems that have become operational and whose designs have stabilized. Air Logistics Centers have original approval authority for Class IV programs costing up to $500,000. Air Force Logistics Command approves programs costing up to $10 million, while Headquarters Air Force (HQ USAF) must approve Class IV mods if the total cost exceeds $10 million for aircraft and missiles, or $2 million for ground equipment. HQ USAF must also approve all Class V modifications (27:18).

The Class IV and Class V modification process is outlined in Figure 2-1 and Figure 2-2, and a more detailed explanation of the key steps of the process can be found in Appendix B and Appendix C. Specific Air Force modification programs are described in Time Compliance Technical Orders (TCTOs). These orders identify the system to be modified, the number of man-hours required, and the skills, material and special tools needed to perform the modification. In addition, they provide a timetable of the planned completion date for installation of the kits (27:1).

Magnitude of the Modification Process

Dollars and man-hours spent to correct deficiencies or make improvements in existing Air Force equipment and non-nuclear munitions are substantial. If one estimated the number of ongoing Class IV and Class V modifications being performed by the five ALCs around the country, one would tally approximately 900 Class IV and 160 Class V modifications being performed (13). Figure 2-3 and Figure 2-4 show nearly 27 million man-hours were spent on Class IV and Class V modification programs in calendar year 1981; and Figure 2-5 gives some estimate of the dollar amounts spent for purchasing kit hardware, engineering development and software data changes for fiscal years 80-83. These dollar amounts do not include modification installation costs (13). These figures are included here to give the reader a feeling of the magnitude of man-hours used and dollars spent on aircraft modifications.

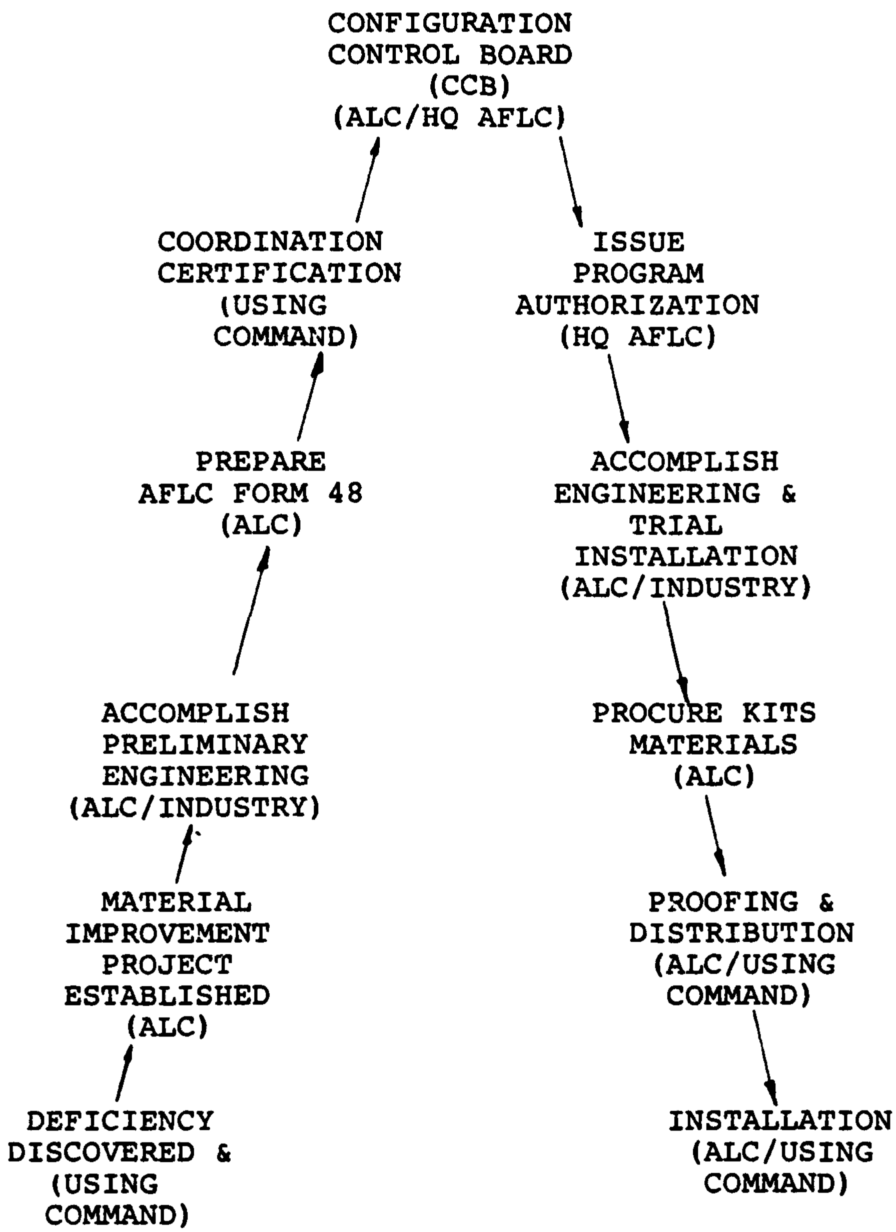


Fig. 2-1. Class IV Modification Processing

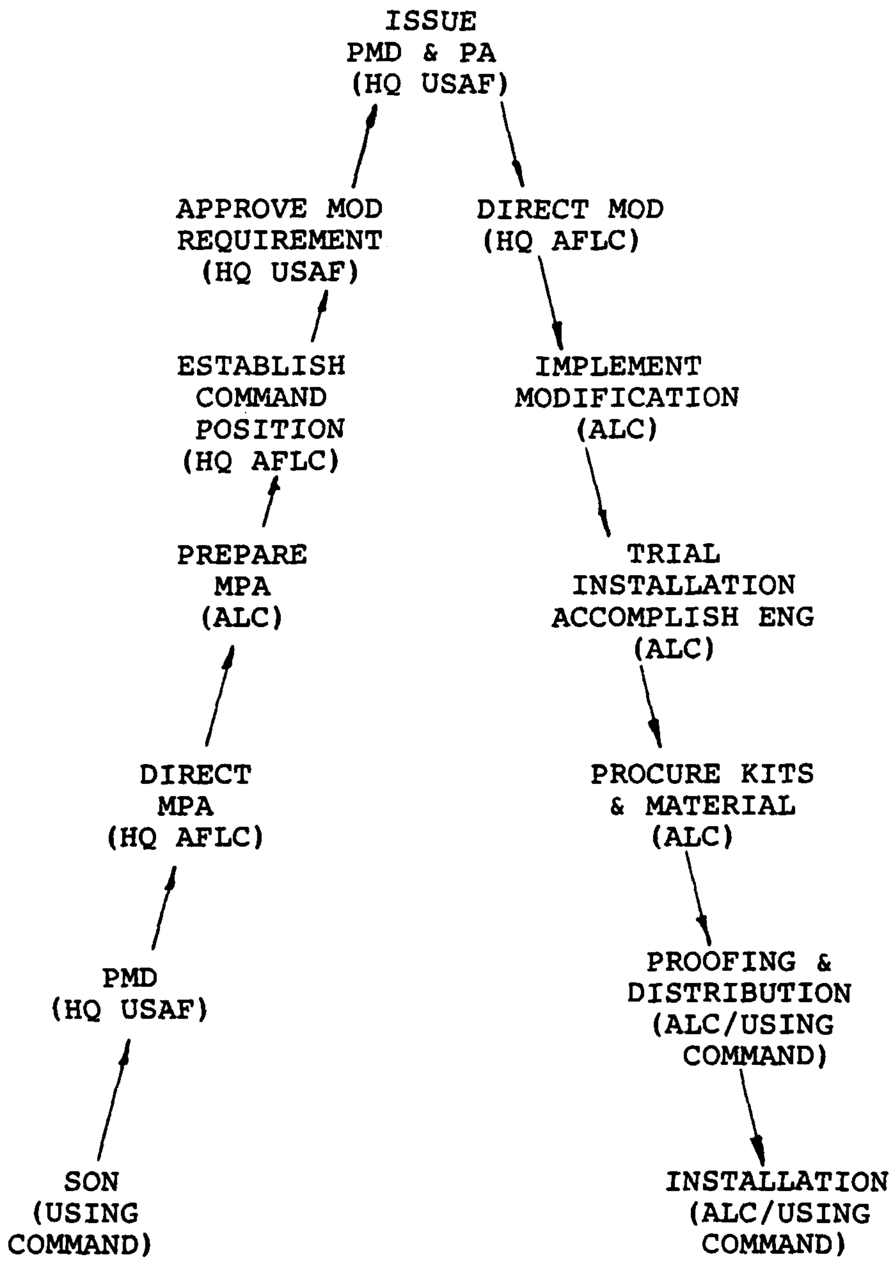
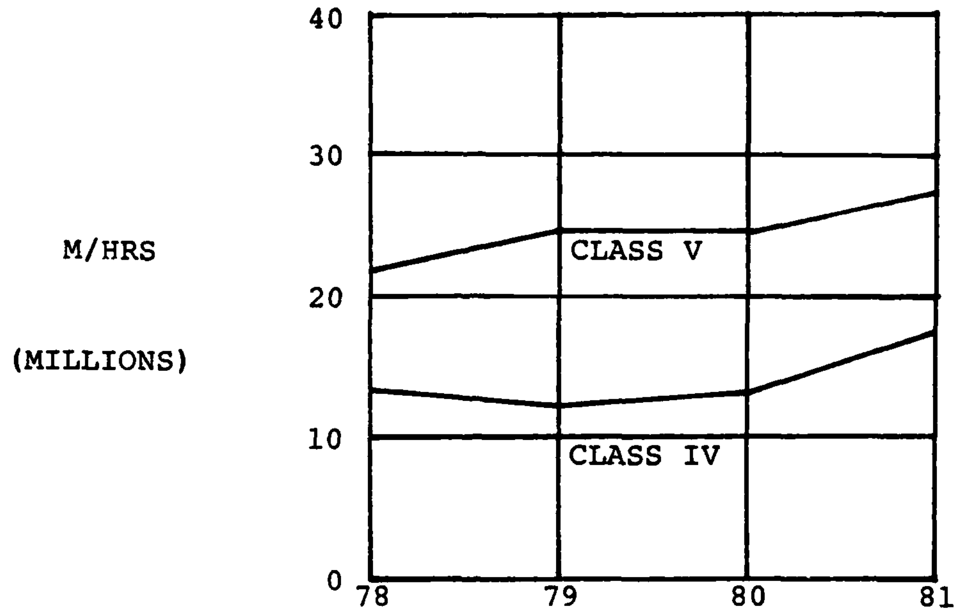


Fig. 2-2. Class V Modification Processing

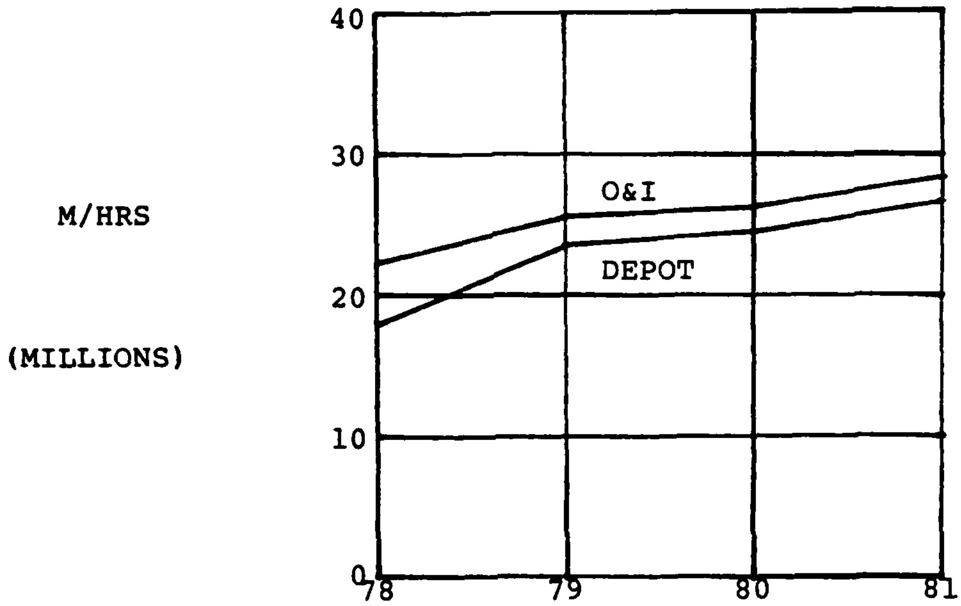


Calendar Year

	78	79	80	81
CLASS V	8.6	13.5	12.6	9.6
CLASS IV	12.5	11.2	12.1	17.7
TOTAL	21.1	24.7	24.7	27.3

as of 31 December

Fig. 2-3. Class IV and V Modification Man-Hours



Calendar Year

	78	79	80	81
O&I	2.4	2.1	1.6	1.6
DEPOT	18.7	22.6	23.1	25.7
TOTAL	21.1	24.7	24.7	27.3

Fig. 2-4. Approved Class IV and V Modification Man-Hours for Organizational/Intermediate and Depot Maintenance

	(IN MILLIONS)			
	FY 80	FY 81	FY 82	FY 83
CLASS V	981.0	1228.6	1342.4	1800.3
CLASS IV	377.3	651.8	810.3	989.5
TOTAL	1358.3	1880.4	2152.7	2789.8

Fig 2-5. Dollar Magnitude of Modification Programs

Summary

This chapter has presented a discussion of policy rules and decision-making in a large organization, modeling and the simulation process, and aircraft modification management policies and procedures. These first two chapters have established an understanding of the system and its related problems. Chapter III will now describe the research methodology employed in this study.

CHAPTER III

RESEARCH METHODOLOGY

Introduction

As previously stated in the problem analysis section of Chapter I, the methodology used to accomplish our research objectives will combine the system dynamics approach with the computer simulation language of DYNAMO. It will be the purpose of this chapter to present the system dynamics approach to problem-solving. A quick overview of the DYNAMO language will be presented during the discussion of the model formulation stage.

The System Dynamics Approach

The system dynamics approach is best suited for solving problems that have at least the following two characteristics; problems that are dynamic in nature, and involve the notion of feedback (23:1-2). Dynamic problems involve quantities which change over time. Some examples of dynamic aircraft modification quantities are the number of modification discrepancies generated each year, the amount of dollars appropriated and obligated, and the number of modification kits on order or ready to install. The system dynamics approach also attempts to understand the behavior of the feedback systems of problems. Feedback may be simply defined as the transmission and return of information. It is generally accepted that organizations, economies and societies, all containing humans, also contain feedback systems. The Air Force modification system is no exception. The key to understanding the modification system, will be the understanding of the behavior of the feedback systems within the modification process. However, this will not be an easy task, for as Richardson and Pugh point out,

> . . . the behavior of systems of interconnected feedback loops often confounds common intuition and analysis, even though the dynamic implications of isolated loops may be reasonably obvious. The feedback structures of real problems are often so complex that the behavior they generate over time can usually be traced only by simulation [23:7].

A modeler using system dynamics methodology would take the view that systems behave as they do for reasons internal to each system, and that feedback structures within the system are responsible for the changes experienced over time (23:15). It follows, therefore, that any external agents believed to have a significant influence or impact upon the system must be considered when constructing a model of the system.

The system dynamics methodology in approaching problems, involves the following stages (23:16):

1. Understanding the system.
2. Problem definition.
3. System conceptualization
4. Model formulation

5. Simulation.

6. Policy analysis.

7. Model use or implementation.

Our basic research strategy will be to follow these stages of the system dynamics approach while accomplishing our research objectives. The rest of this chapter will be devoted to explaining in a little greater detail, the forementioned stages. It is important to keep in mind when progressing through these stages, that the stages themselves overlap and that the process is an iterative one, as shown in Figure 3-1. This approach begins with an understanding of the system. This understanding is enhanced by the modeling process which, in turn, further aids the modeling effort (23:16).

System Understanding, Problem Identification and System Conceptualization

The first three steps in the development of a policy model of the aircraft modification process have been accomplished and are presented in Chapters I and II of this thesis. An initial understanding of the system's operation was accomplished with an extensive review of the available literature, and through interviews with various Air Force aircraft modification managers. From this starting point, various problems in the system were identified and defined. It is very important during the early stages of system conceptualization that the modeler remembers to focus on the

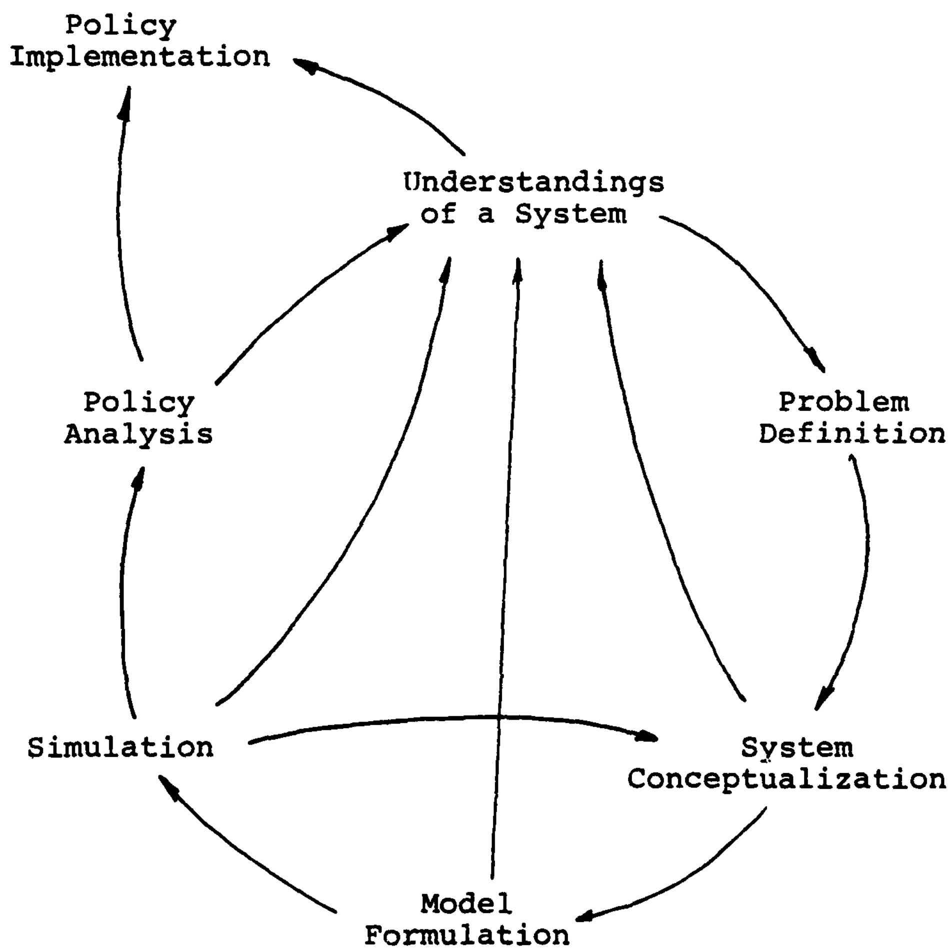


Fig. 3-1. Overview of the System Dynamics
Modeling Approach [23:17]

problem and not the system. This becomes crucial when deciding which variables to include, and which variables not to include, in the normal model's feedback structure. Problem identification and definition are realized through formulation of a problem statement and analysis and development of the thesis research question. From the research question, research objectives were established. The purpose of the model then becomes to act as a tool in aiding the modeler to accomplish these research objectives.

While gaining an understanding of the systems' operation and identifying problems, systems conceptualization was also taking place. That is, ideas concerning system goals were formulated, system boundaries were established and pertinent system variables identified. Through the use of causal loops and flow diagrams, a formal aircraft modification model began to take shape, and a feedback structure developed.

Formal Model Formulation

The formal model formulation stage begins as causal loops and flow diagrams are drawn establishing the systems feedback structures and system boundaries. At this time, the system is divided into sectors. System sectors provide a framework for the grouping together of like processes and resources. This approach not only aids the modeler by helping him to focus in on appropriate feedback systems, but allows the modeler to run, trouble-shoot, and correct errors in his model a sector at a time, which when compared to attempting this on an entire model, saves considerable time. Determining the appropriate sectors to be included in the model requires considerable analysis, and the final decision of what is or is not included, rests with the model builders. For the aircraft modification process, there are four main sectors, several of which are further broken down into sub-sectors. The four main sectors are a need sector, a financial sector, a requirements sector and a production sector. Briefly, the need sector represents factors that interact to create potential modification requirements. The requirements sector represents the approval process for modifications, while the financial sector ties the aircraft modification process to the planning, programming and budgeting cycle. The production sector represents the purchase and installation of modifications.

The model formulation stage also includes the translation of flow diagrams representing model structure into equations. This requires the selection of an appropriate computer simulation language to be used in conjunction with the system dynamics approach. DYNAMO, the language selected for this thesis, is a merger of the words "dynamic models." This language was developed to be used in modeling systems so that their dynamic behavior over time could be traced (imitated, simulated) by a computer (23:67). Using the

DYNAMO language, equations are written based on the previously constructed flow diagrams. Figure 3-2 describes the principle symbols used in flow diagrams. Readers who are not familiar with the technique of flow diagramming or the writing of DYNAMO equations from flow diagrams, may refer to Richardson and Pugh's Introduction to System Dynamics Modeling with DYNAMO, for a more detailed description. Once system structure has been translated into equations, the model testing phase can begin.

Simulation, Policy Analysis and Policy Implementation

Prior to using a model for policy analysis or policy implementation, several simulation runs should be made to check the model for coding or formatting errors. A model free of "fatal errors," however, does not necessarily mean that the model is validated and ready for policy testing. If genuine confidence in the model is to be established, conceptual errors involving system structure and operation, must also be checked for and eliminated. It is at this point that the modeler must come to terms with the concepts of model verification and validation.

Verification is the process of insuring that a model behaves in the manner in which it was intended to behave (25:210). For example, the checking of equations to insure their outputs are indeed close to what they are intended to be, and not some unrealistic result.

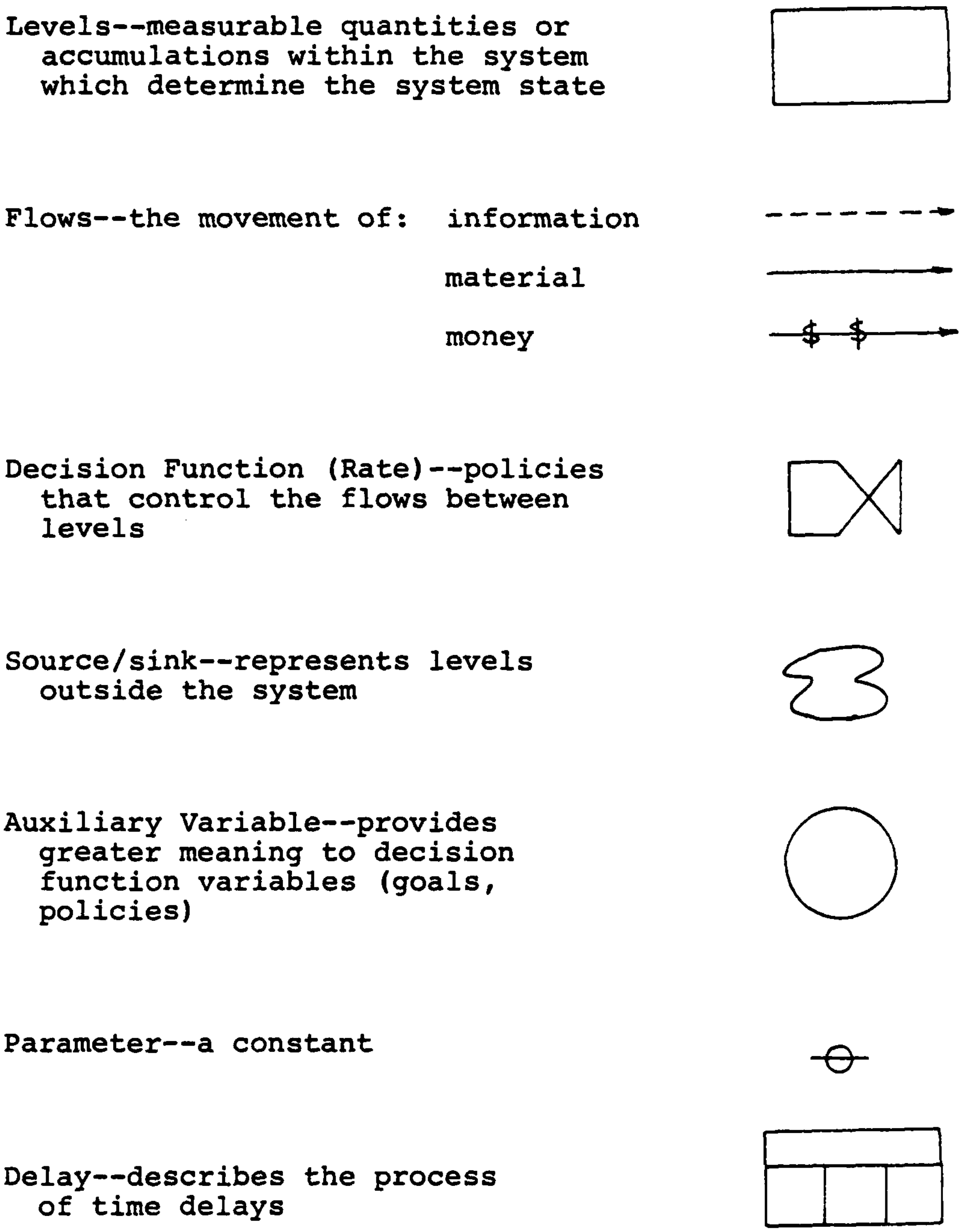


Fig. 3-2. Principle Symbols Used in Flow Diagrams [11:7-3]

Validation, on the other hand, is the process of comparing the model's behavior with the real system's behavior (25:210). One may view verification as being concerned more with the correctness of a model's structure or accuracy of model parameters, while validation focuses on the realism of the model's output. Shannon states the process of validation as ". . . bringing to an acceptable level the user's confidence that any inference about a system derived from the simulation is correct [8:29]."
J. W. Forrester equates the term validity with significance, and believes that the

> . . . validity (or significance) of a model should be judged by its suitability for a particular purpose. A model is sound and defendable if it accomplishes what is expected of it [10:115].

Despite extensive literature dealing with validation procedures, the problem of actually validating a simulation model is very difficult. One may ask, when is a model considered valid? Richardson and Pugh state their view by quoting Greenberger, Crensen and Crissy. "No model has ever been or ever will be thoroughly validated . . . 'useful,' 'illuminating,' or 'inspiring confidence' are more apt descriptors applying to models than 'valid' [23:310]." Richardson and Pugh (4:310) go on to state their definition of validation as the formal processes that lead people to place confidence in a model.

The "formal processes" used to establish confidence in this model, are taken from an article entitled, "Tests for Building Confidence in System Dynamics Models." by J. W. Forrester and Peter M. Senge (17:209-228). Forrester and Senge believe there is

> . . . no single test which seems to validate a system dynamics model. Rather, confidence in a system dynamics model accumulates gradually as the model passes more tests and as new points of correspondence between the model and empirical reality are identified [17:209].

The series of tests this thesis team will follow will be the core tests suggested by Forrester and Senge (32:227). They are:

1. Tests of Model Structure
    a. Structure Verification
    b. Parameter Verification
    c. Extreme Conditions
    d. Boundary Adequacy
    e. Dimensional Consistency
2. Tests of Model Behavior
    a. Behavior Reproduction
    b. Behavior Anomaly
    c. Behavior Sensitivity
3. Tests of Policy Implications
    a. Changed-Behavior Prediction
    b. Policy Sensitivity

Structure verification means comparing structure of a model directly with structure of the real system that the model represents. Parameter verification means comparing model parameters to knowledge of the real system to determine if parameters correspond conceptually and numerically to real life. The extreme condition test is testing the model's behavior under extreme combinations of levels in the system being represented. The boundary adequacy test considers structural relationships necessary to satisfy a model's purpose. The dimensional consistency test entails dimensional analysis of a model's rate equations.

The behavior reproduction test, is a test of model behavior that examines how well model-generated behavior matches observed behavior of the real system. The behavior anomaly test is used to discover anomalous features of model behavior which sharply conflict with behavior of the real system. The behavior sensitivity test focuses on sensitivity of model behavior to changes in parameter values.

The changed behavior prediction test asks if a model correctly predicts how behavior of the system will change if a governing policy is changed. Policy sensitivity testing can indicate the degree to which policy recommendations might be influenced by uncertainty in parameter values.

Passing the various validation tests listed above should instill in the model builder and the model user, the confidence that their model does represent the real system closely enough to continue with the next stage of the system dynamics approach, that of policy analysis and implementation.

Reaching this final stage of the system dynamics approach to problem-solving has involved a lot of time and effort on the modeler's part and one might believe the work is now finished. Nothing could be further from the truth. The purpose of developing the model was to use it as a tool to aid the user in analyzing proposed policy changes and forecasting the possible results of their implementation. Until now, all the modeler's time has been spent on building this tool. Only now is the tool ready for use. It is during this stage of the system dynamics approach, that the generation of new insights will most likely occur. This hopefully will cause the modeler and user to reconceptualize their ideas about the system, reformulate the model, rerun the simulation and gain even more profound insights into the systems operation or the solution to a problem. This is in keeping with the iterative process of the system dynamics approach.

Occasionally the model will exhibit some behavior that at first contradicts the modelers intuitions and, later, with the aid of the model, is seen as a clear implication of the structure of the system. This has come to be known as "counterintuitive behavior" (23:318). It has been observed that complex feedback systems tend to exhibit counterintuitive behavior (23:318). This may occur due to the fact that long-term responses are characteristically the opposite of short-term responses, and one's intuitions are often based on one or the other perspective, seldom on both (23:318).

Summary

The system dynamics methodology provided the basic research approach to develop a dynamic policy model of the aircraft modification process. This chapter has outlined the basic steps that were taken during the research process. Although the steps infer a sequential approach, the nature of the model building was iterative. Many of the steps were retaken as new information became available to enrich the model. In Chapter IV, the actual formulation of aircraft modification model equations from the flow diagrams will be discussed.

CHAPTER IV

FORMULATION OF THE MODEL

Introduction

Chapters I through III have established the need and the methodology for a dynamic policy model of the Air Force Aircraft Modification System. Continuing to follow the system dynamics approach as outlined in Chapter III, this chapter will discuss the formulation of the aircraft modification model. As stated in Chapter III, the model has been divided into four main sectors for ease of conceptualization and testing. They are:

1. Need sector
2. Requirement sector
3. Financial sector
4. Production sector

Briefly, the need sector represents factors that interact to create potential modification requirements. The requirements sector represents the approval process for modifications, while the financial sector ties the aircraft modification process to the planning, programming and budgeting cycle. Finally, this model's production sector will represent the purchase and installation of modifications.

To acquaint the reader with the interactions of the entire system, a causal loop diagram presenting a general overview of the aircraft modification model is shown in Figure 4-1. The model's need sector is structured around the generation of U.S. Air Force Class IV and Class V aircraft and logistic deficiencies. Class IV deficiencies include safety deficiencies (Class IV A), engineering deficiencies (Class IV B), and logistic deficiencies (Class IV C). Class V deficiencies are created by a lack of weapon system capability. Several factors influencing the generation of deficiencies include an enemy's weapon system capability, U.S. weapon system capability, technology available, and the age, reliability and maintainability of our own systems. As enemy weapon system capability and technology availability increase, the desired weapon system capability tends to increase. However, as U.S. weapon system capability increases, desired weapon system capability will appear to decreased. An increase in desired weapon system capability causes modification requirements to increase. Modification requirements will also increase as the number of safety deficiencies and engineering deficiencies increase. Engineering deficiencies increase as systems grow older, due to a decrease in reliability and maintainability of the aircraft. Generated deficiencies become modification requirements after passing through the Air Force's modification approval process, represented in

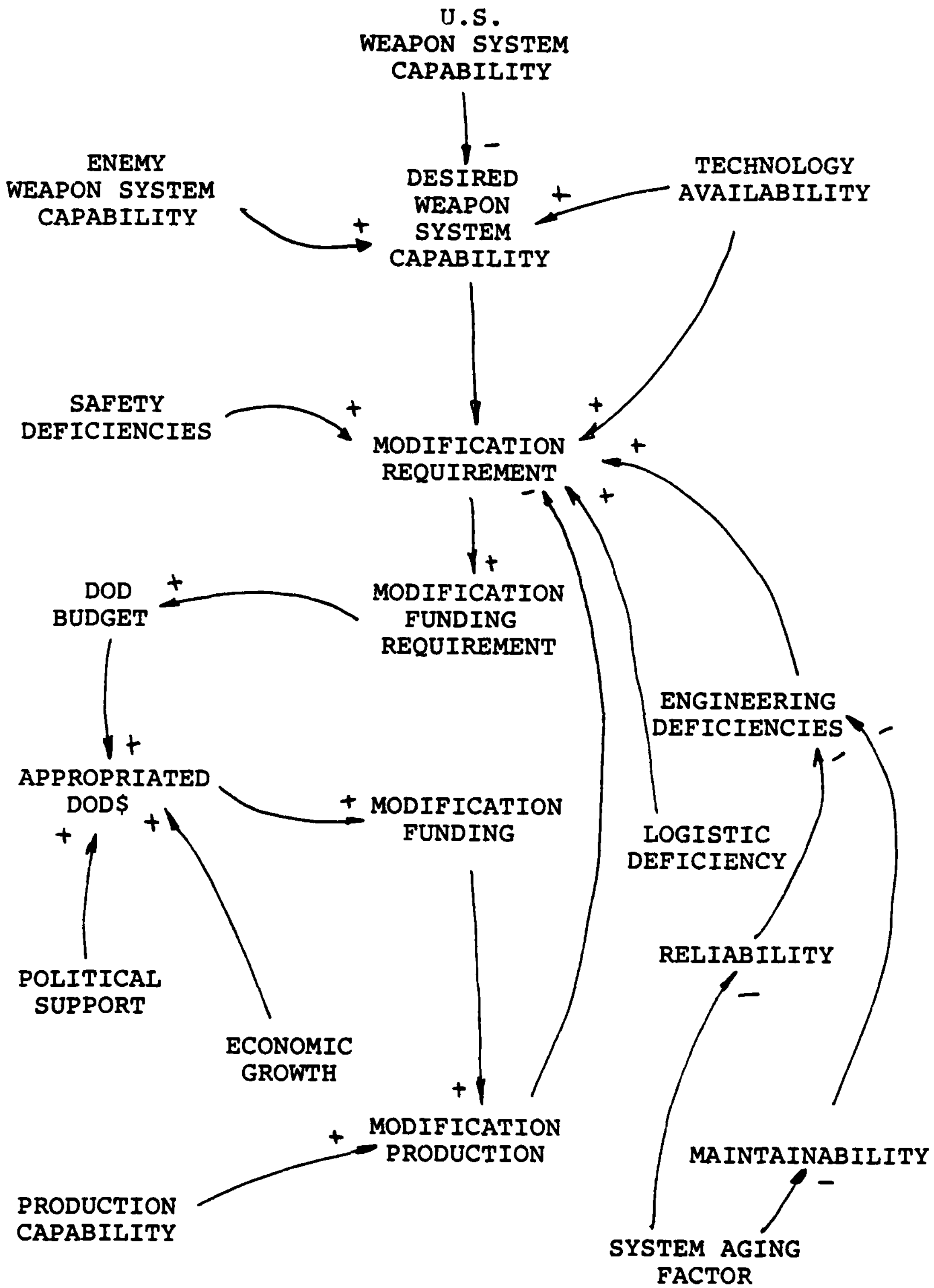


Fig 4-1. General Overview of Aircraft Modification Model

this model by the modification requirement sector. Once approved, modifications compete with other programs for funding. This will be represented by the financial sector of the model, and includes such influencing factors as Department of Defense's (DOD's) budget, political support for DOD's budget and economic well-being of the nation. As modification funding requirements increase, the DOD budget will increase. The level of DOD appropriated dollars is increased when there is political support, and when the nation's economic condition is good. As the DOD appropriated dollars increase, the level of modification funding will also increase.

Once a modification has been funded, modification kits are procured and installed. This phase of the real system is represented by the model's production sector. A factor influencing modification production is production capability. Production capability is influenced by such factors as the level of production personnel and production facilities.

Having examined the aircraft modification system's overview, the formulation of individual sectors will now be discussed in detail. Each sector will be developed in three steps: first, a causal loop diagram is proposed; second, the flow diagram is developed; and third, the DYNAMO equations are written. A listing of all the causal loop diagrams, flow diagrams and DYNAMO equations are attached in Appendix E.

Need Sector

The need sector is divided into four subsectors. They are safety deficiencies, engineering deficiencies, logistics deficiencies and capability deficiencies. The need sector describes the generation of deficiencies and the factors that influence the rate of generation.

Class IV A Safety Deficiency Subsector

The Class IV A safety deficiency subsector describes the generation of safety deficiency and the factors that affect the rate of generation.

Discussion of the Causal Loop Diagram. The Class IV A safety deficiencies need is a result of an aircraft component's or system's failure to perform its intended function, and as a result of this failure, the safety of personnel and equipment are in question. If modification is not performed, the probability of injury to people and equipment will be high. Therefore, the Class IV A safety deficiencies constitute a major portion of funded modifications. Figure 4-2 presents the causal loop diagram describing the factors that generate Class IV A needs.

Safety deficiencies are reported by the operating commands as they arise. The operating commands will initiate paperwork for system managers' investigation of the deficiencies. Safety deficiencies arise through normal use of the aircraft. The number of deficiencies is amplified by

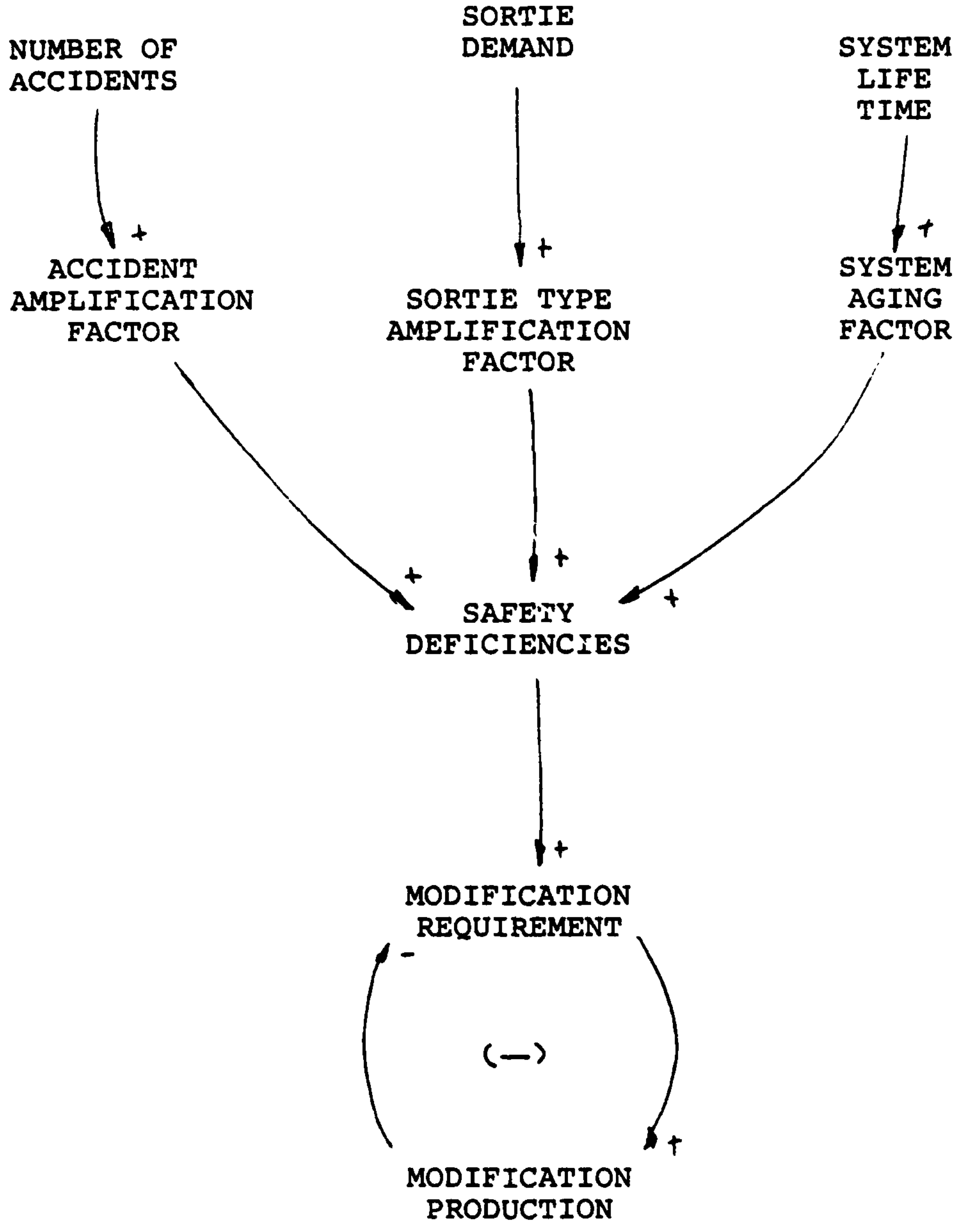


Fig 4-2. Safety Deficiency Causal Loop Diagram

the sortie type flown, the system aging factor and the accident amplification factor. The number of safety deficiencies increases as the sortie type amplification factor, the system aging factor and/or the accident amplification factor increases. As the number of safety deficiencies increase, the level of modification requirements increase. The modification requirements are then reduced by the production or installation of modifications correcting the deficiencies.

Discussion of the Flow Diagram and Dynamo Equations. The flow diagram for this subsector can be seen in Figure 4-3. Table 4-1 lists the variables in this subsector. The flow diagram was developed from the conceptual causal diagram. Using the flow diagram as a guide, the DYNAMO equations were developed in the following way:

The Class IV A deficiencies generation is a function of the Weapon System Aging Factor (WSAP), the Sortie Type Amplification Factor (STAF), the Aircraft and Personnel Accident Amplification Factor (APAAF), and a normal deficiencies generation rate (ANSD). The equations pertaining to these functions are as follows:

```
L   CL4A.K    = CL4A.J+DT *(CL4AGR.JK - CL4ADR.JK)
R   CL4AGR.KL = ANSD.K *WSAF.K*STAF.K*APAAF.K
R   CL4ADR.KL = CL4A.K/.5
```

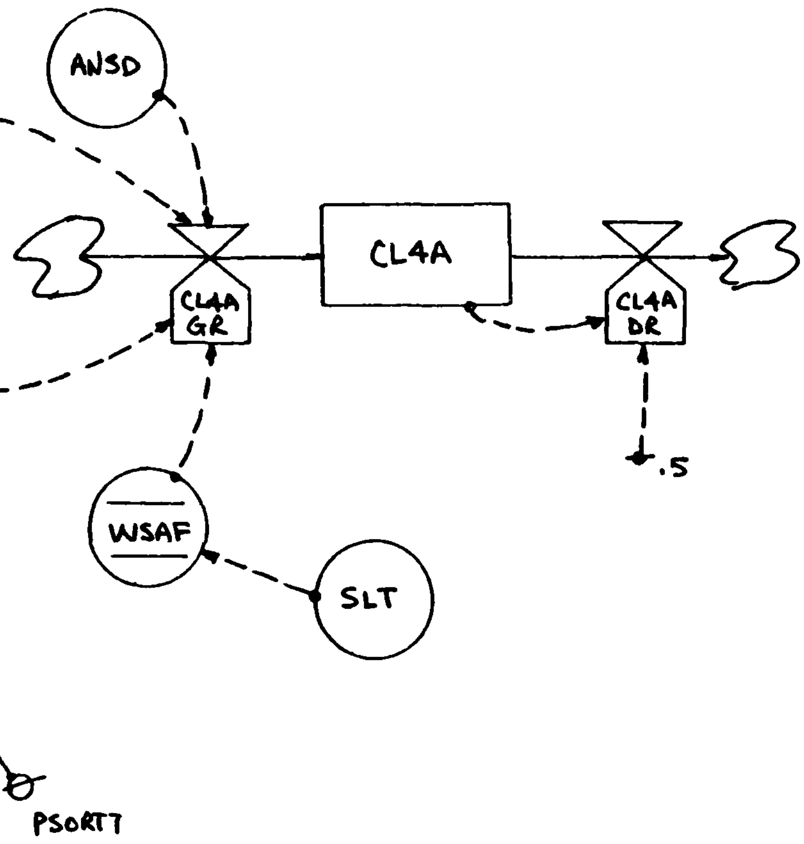


Fig. 4-3. Safety Deficiency Flow Diagram

TABLE 4-1

VARIABLES APPEARING IN FIGURE 4-3

Variable	Definition
CL4A	Class IV A Safety Deficiences
CL4AGR	CL4A Growth Rate
CL4ADR	CL4A Release Rate
ANSD	Average No. of Safety Deficiencies per Period
WSAF	Weapon System Aging Factor
STAF	Sortie Type Amplification Factor
APAAF	Aircraft/Personnel Accident Amplification Factor
NOA	Number of Accidents
NOAC	Constant for NOA
SLT	System Life Time (Years Since Production)
ISLT	Initial System Life Time
SORTYP	Sortie Type
PSORT1	Percent of VFR Flying Sorties
PSORT3	Percent of Normal Training Sorties
PSORT5	Percent of Redflag Sorties
PSORT7	Percent of War Employment Sorties

The four factors that made up the CL4A growth rate are developed in separate auxiliary equations.

```
A          ANSD.K = ANSDI
C          ANSDI  = 2.5
```

This auxiliary equation describes the average number of safety deficiencies per period. The number, ANSDI, was computed by averaging the total number of new safety deficiencies received by AFLC/LOAP (2,30). It is difficult to predict when and how many deficiencies will arise. Therefore, we chose to use an average number of deficiencies and modify this number by other factors.

```
A   WSAF.K = TABLE (WSAFT,SLT.K,0,20,2)
T   WSAFT  = 10/3/1.3/1.0/1.0/1.0/1.0/1.0/1.0/1.3/3.0/10.0
A   SLT.K  = TIME.K/12+ISLT
```

The weapon system aging factor (WSAF) is an amplification factor that increases the number of safety deficiencies. It takes its information from system life time (SLT). SLT represents the average life time of major USAF operating aircraft. The weapon system aging factor followed the generally accepted "bath-tub" curve as seen in Figure 4-4. The WSAFT table was adequately validated by comparing generated F-4 safety deficiencies and generated A-10 safety deficiencies. F-4s are more into their normal operating life, while A-10s have just been put into service within the last two years.

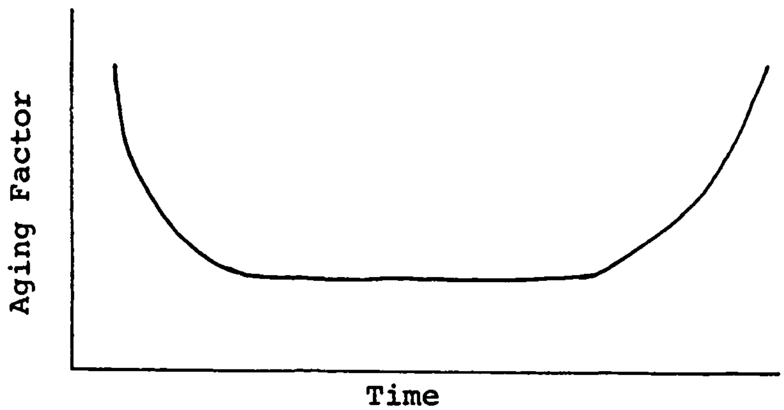


Fig. 4-4. Bath-Tub Curve

The number of deficiencies reported by the field for A-10s were quite an order of magnitude larger as compared to the F-4s. The SLT is determined simply by the weapon system's average time since production plus the model simulation time in years.

```
A    STAF.K    = TABLE(STAFT,SORTYP.K,1,7,2)
T    STAFT     = 1.0/1.03/1.06/1.09
A    SORTYP.K  = PSORT1*1+PSORT3*3+PSORT5*5+PSORT7*7
C    PSORT1    = .40
C    PSORT3    = .50
C    PSORT5    = .10
C    PSORT7    =  0
```

The sortie type amplification factor (STAF) is a table function taking its information from the sortie type flown. The sortie type flow is the weighted sum of the four different types of sorties: visual flight rule (VFR), normal training, Red Flag (simulates combat) and war employment. The weight given to each of these types is based on the percentage of the type of sortie flown by the weapon system. These percentages can be changed as demand for particular sortie types arise. They are entered here as constants which managers can alter to match the sortie type demand.

```
A    APAAF.K = TABLE (APAAFT,NOA.K,0,5,1)
T    AFAAFT  = 1.0/1.0/1.04/1.05/1.05/1.05
A    NOA.K   = NOAC
```

The aircraft and personnel amplification factor is hypothesized, based on the number of accidents which occur. The more accidents that occur, the more are perceived deficiencies reported by the field.

The last equation for this subsector is the Class IV A deficiencies reporting rate

```
R    CL4A.DR.KL = CL4A.K/.5
```

As deficiencies are discovered, they are reported to the respective aircraft system manager for review, and enter the modification approval process. The reporting time entered here is .5 period or two weeks.

Class IV B Engineering Deficiencies Subsector

The Class IV B engineering deficiencies subsector describes the generation of engineering deficiencies and the factors that affect the rate of generation.

Discussion of the Causal Loop Diagram. The causal loop for this subsector is presented in Figure 4-5. Class IV B engineering deficiencies are related to maintainability and reliability. These types of modifications are required to restore the aircraft's intended or designed operating capability. The number of engineering deficiencies increase as the reliability discrepancy increases and as maintainability decreases. Reliability discrepancy is a function of the perceived reliability and the desired reliability. Perceived reliability is the level of reliability as perceived by the field. Maintainability is a function of the equipment support, maintenance skill level and weapon system complexity.

Engineering deficiencies are reported to the system manager in the same manner as the safety deficiencies. As these engineering deficiencies are reviewed and approved, they become modification requirements eligible to compete for modification funding.

Discussion of the Flow Diagram and Equations. The flow diagram is presented in Figure 4-6. Table 4-2 lists the variables in this subsector. The equations developed from the flow diagram are as follows:

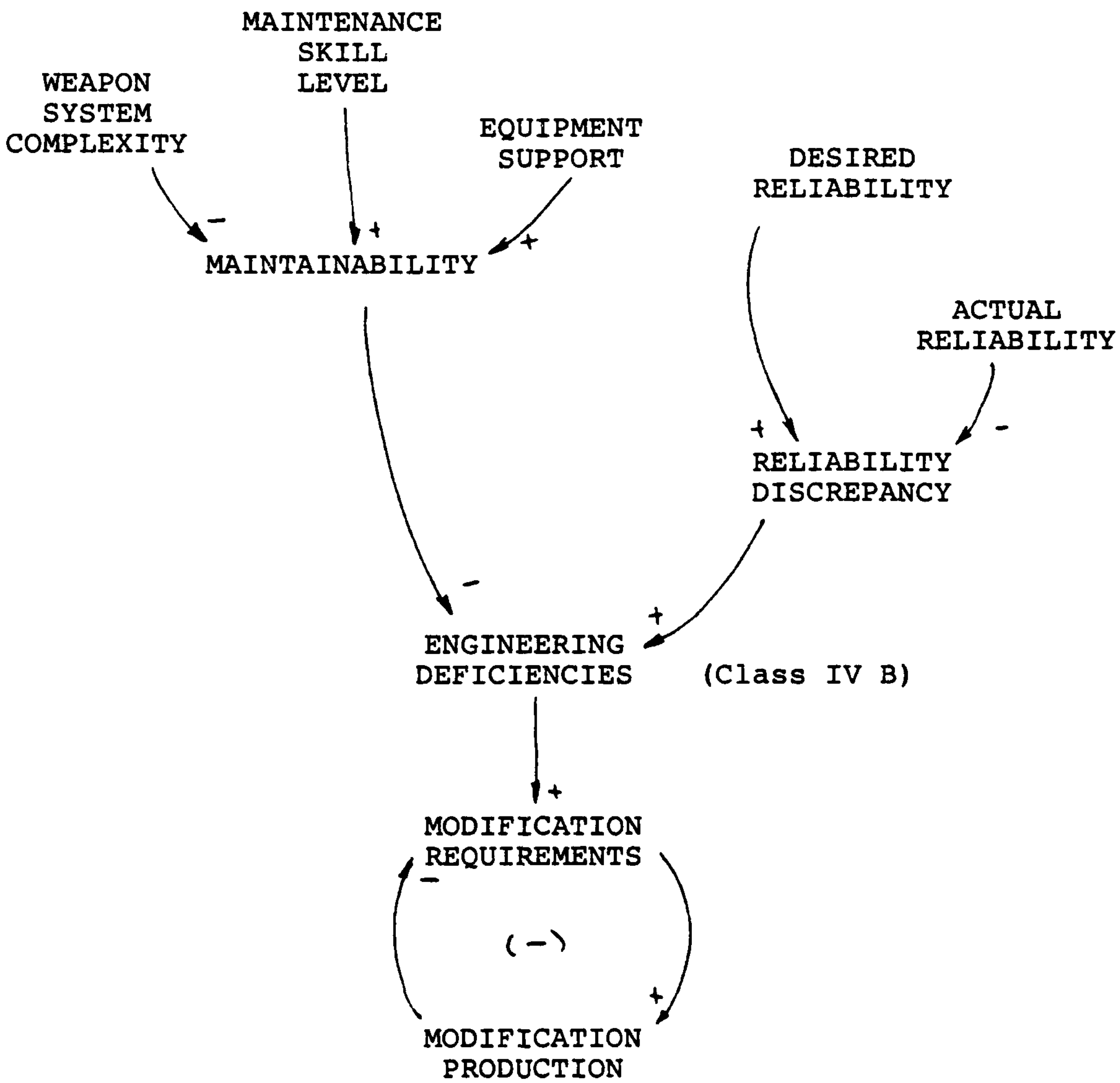


Fig. 4-5. Engineering Deficiency Causal Loop Diagram

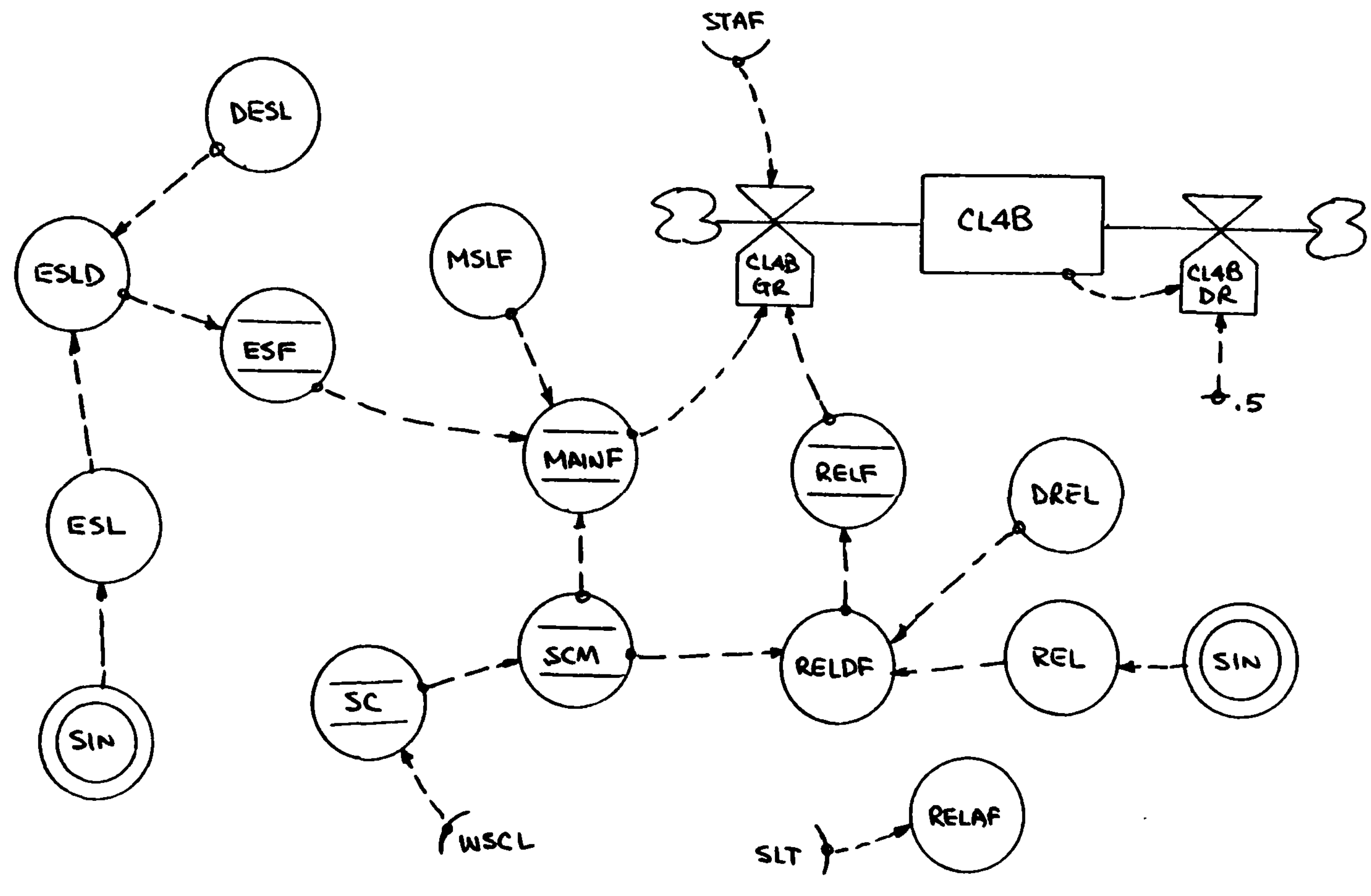


Fig. 4-6. Engineering Deficiency Flow Diagram

TABLE 4-2

VARIABLES APPEARING IN FIGURE 4-6

Variable	Definition
CL4B	Class IV B Engineering Deficiencies
CL4BGR	CL4B Growth Rate
CL4BDR	CL4B Deficiencies Release Rate
RELF	Reliability Factor
MAINF	Maintainability Factor
STAF	Sortie Type Amplification Factor
RELDF	Reliability Discrepancy
REL	Reliability Level
DREL	Desired Reliability Level
SCM	System Complexity Modifier
DRELC	Desired Reliability Constant
ESF	Equipment Support Factor
MSLF	Maintenance Skill Level Factor
ESL	Equipment Support Level
DESL	Desired Equipment Support Level
ESLD	Equipment Support Discrepancy
MSLFC	Maintenance Skill Level Constant
SC	System Complexity
WCSL	Weapon System Capability Level
SLT	System Life Time
RELAF	Reliability Aging Factor

```
L    CL4B.K    = CL4B.J+DT* (CL4BGR.JK-CL4BDR.JK)
R    CL4BGR.KL = (RELF.K+MAINF.K) * STAF.K
R    CL4BDR.KL = CL4B.K/.5
```

The level of engineering deficiencies are increased by generation of reliability-related deficiencies, plus maintainability-related deficiencies and are further amplified by the type of sortie flown, as we can see from the above equations. To determine the growth rate of these types of deficiencies is difficult, so DYNAMO table functions are used to capture relative relationships.

```
A    RELF.K    = TABLE(RELFT,RELDF,K,0,1,.2)
T    RELFT     = 20/12/12/10/8/6
A    RELDF.K   = REL.K/DREL.K SCM.K
A    REL.K     = (.8+.1*SIN(6.283 TIME.K/12)) RELAF.K
A    DREL.K    = DRELC
A    SCM.K     = TABLE(SCMT,SC.K,1,10,1)
T    SCMT      = 1.0/1.0/1.0/1.0/1.0/.99/.98/.97/.96/95
A    SC.K      = TABLE(SCT,WSCL.K,1,10,1)
T    SCT       = 5/5/5/5/5/5.6/7.5/8.9/9.9/10.0
A    RELAF.K   = TABLE(RELAF,SLT.K,0,20,2)
T    RELAFT    = .01/.5/.75/1.0/1.0/1.0/1.0/1.0/.8/.6/.4
```

Reliability of aircraft subsystems, such as avionics, engine or structure, are measured in mean time between failures (MTBF). When the MTBF falls to an unacceptable level, modification to the subsystem, either through replacement of the total subsystem or redesign of the failure portion, will be required to keep the aircraft flying at its intended capacity. The reliability measurement here is a relative measure of the total aircraft system reliability. Reliability is affected by an aging factor (RELAF). This again is to capture the bath-tub curve concept. The system is usually less reliable during its earlier years of operation, due to design deficiencies. As these deficiencies are discovered and corrected, the system will be operating at its designed level of reliability throughout most of its life time. Toward the last years of the system life, the reliability level will drop due to wearing out and breakage of components. This is the reason why the factor of RELAF is included.

REL is generated by a sine function which varies from .7 to .9. The REL is then divided by the desired level of reliability (DREL), entered here as 1.0, and modified by multiplying by the system complexity modifier. The resulting reliability discrepancy contributes to the generation of Class IV B deficiencies. The system complexity modifier is included here to capture the hypothesis that as the system becomes more complex in design, the reliability of the system will decrease.

```
A     MAINF.K     = TABLE(MAINFT,SCM.K*ESP.K*MSLF.K,0,1,.2)
T     MAINFT      = 20/15/12/10/8/6
A     ESF.K       = TABLE(ESFT,ESLD.K,0,1,.2)
T     ESFT        = .70/.85/.90/.93/.997/.99
A     ESLD.K      = ESL.K/DESL.K
A     ESL.K       = .8+.1 SIN (6.283*TIME.K/12)
A     DESL.K      = DESLC
C     DSLC        = 1.0
A     MSLF.K      = MSLFC
C     MSLFC       = .95
```

Maintainability of an aircraft subsystem can be measured in several ways such as mean-time-to-repair, maintenance man-hour per flying hour, or mean down time (AFR 80-5, AFR 80-14). The maintainability factor (MAINF) used here captures the idea of the relative ease of restoring the aircraft to its operating condition. The factors involved in determining MAINF are the system complexity modifier (SCM), the equipment support factor (ESF), and the maintenance skill level (MSLF).

SCM is included here because as the system becomes more complex, the relative ease in maintaining the aircraft will decrease and, thus, increase the Class IV B deficiencies.

Equipment support level is the second contributing factor to determine the deficiency generation. When the field is limited by test and support equipment, aircraft down time for maintenance will be longer than desired. If not corrected, either by increasing the equipment support level or modifying the system to require less maintenance, there will be an increase in Class IV B deficiencies.

The third contributing factor is the maintenance skill level factor. It is a measure of the effectiveness or productivity of the maintenance personnel. It is included because if affects directly the readiness and the down time of aircraft. Maintenance skill level can be increased by emphasizing training. It is entered here as a constant for experimenting purposes.

Class IV C Logistic Deficiencies Subsector

The Class IV C logistic deficiencies subsector describes the generation of logistic deficiencies and the factors that affect the rate of generation.

Discussion of the Causal Loop Diagram. The causal loop diagram of this subsector is presented in Figure 4-7. The logistics deficiencies are results of the inability to support the aircraft weapon system logistically. Typical logistic deficiencies involve systems having high logistic support costs, standardization of aircraft weapon subsystems, and so forth. Interviews with modification managers reveal little about how logistics deficiencies were generated except that older aircraft usually have more logistics deficiencies. As the system gets more complex, there is also a tendency that more logistic deficiencies will occur.

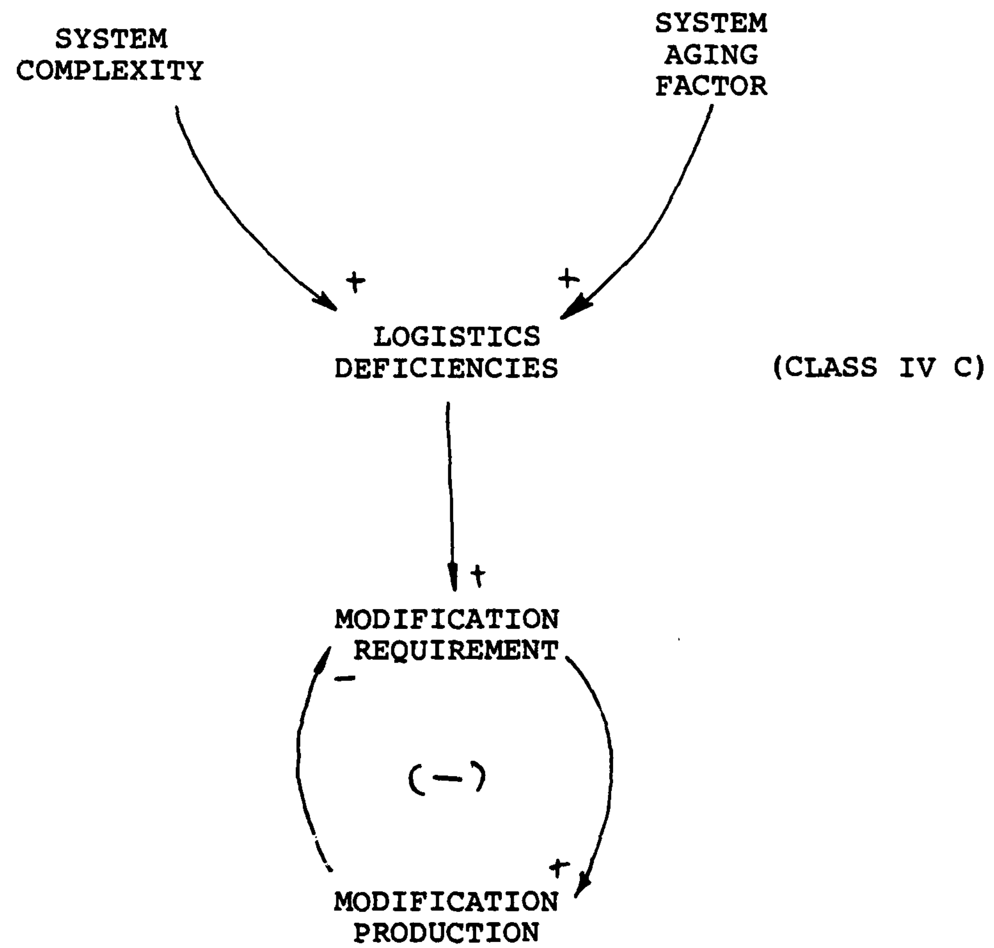


Fig. 4-7. Logistics Deficiency Causal Loop Diagram

As more logistic deficiencies occur, modification requirements will increase. Modification requirements are, in turn, reduced through modification production. The causal loop diagram depicts the conceptual relationship.

Discussion of the Flow Diagram and Equations. The flow diagram is contained in Figure 4-8. Table 4-3 lists the variables in this subsector. The equations for the flow diagram are presented below:

```
L   CL4C.K     = CL4C.J+DT* (CL4CGR.JK - CL4CDR.JK)
R   CL4CGR.KL = LSRF.K
R   CL4CDR.KL = CL4C.K/.5
```

The level of Class IV C logistic deficiencies (CL4C) increases as the logistic support requirement factor (LSRF) increases. The CL4C is decreased by the reporting of the deficiencies to the responsible system manager for review and approval. Once they are approved, they will be included for modification funding competition. This class of deficiency receives the lowest priority in obtaining modification funding.

```
A   LSRF.K = TABLE(LSRFT,SLF.K*SCM.K,0,1,.2)
T   LSRFT  = 4.0/3.5/3.0/2.5/2.0/1.5
A   SLF.K  = TABLE(SLFT,SLT.K,0,20,2)
T   SLFT   = .01/.40/.60/1.0/1.0/1.0/1.0/1.0/1.0/.75/.5
```

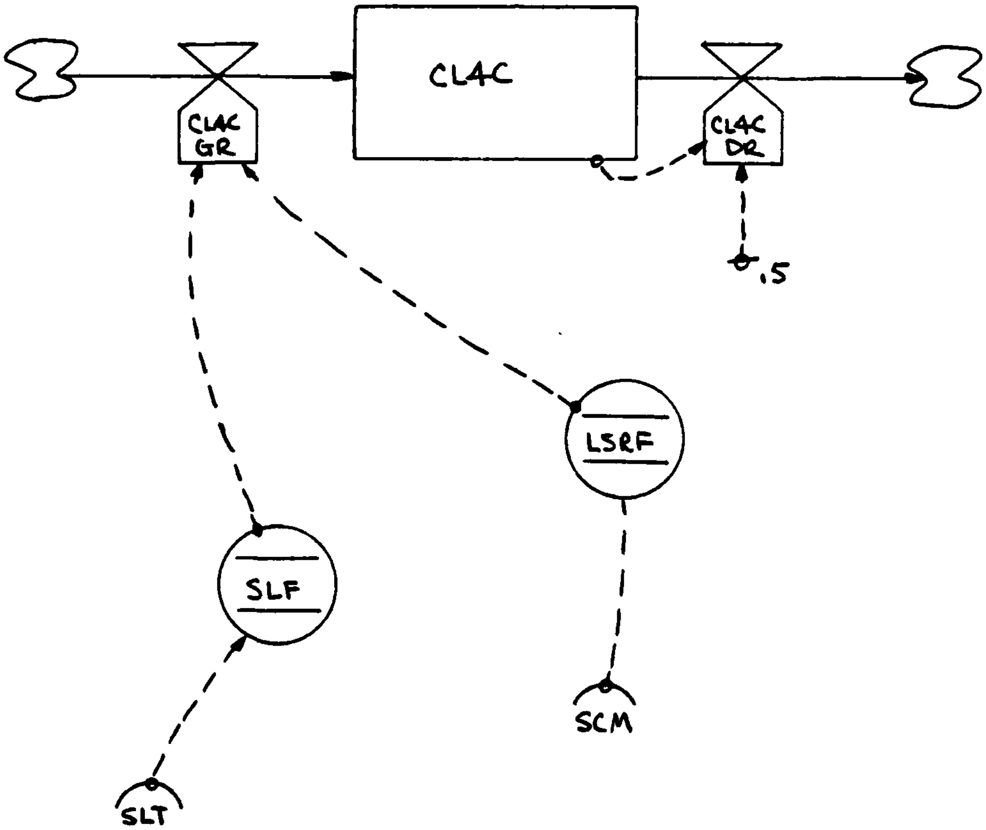


Fig. 4-8. Logistics Deficiency
Flow Diagram

TABLE 4-3

VARIABLES APPEARING IN FIGURE 4-8

Variable	Definition
CL4C	Class IV C Logistics Deficiencies
CL4CGR	CL4C Growth Rate
CL4CDR	CL4C Release Rate
CL4CC	Initial Value for CL4C
LSRF	Logistics Support Requirements Factor
SLF	System Life Factor
SLT	System Life Time
SCM	System Complexity Modifier

The logistic support requirement factor is determined by the product of system life factor (SLF) and system complexity modifier (SCM). The system life factor is a measure of the contribution to the generation of Class IV C logistic deficiencies. This factor is derived from the number of years since the aircraft began operational service. The system complexity modifier is determined by the system complexity and is used to modify the system life factor. This is to establish the relationship that as the system becomes more complex, more Class IV C deficiencies are generated. The LSRFT table value was established by analyzing the priority list of modification requirements.

Class V Capability Deficiencies Subsector

The Class V capability deficiencies subsector describes the generation of capability deficiencies and the factors that affect the rate of generation.

Discussion of the Causal Loop Diagram. While Class IV modifications are restoring efforts, Class V modifications are improving or adding on new weapon system capabilities. Class V modification generations are a result of mission area analysis, which compares the U.S. weapon system capability level and the enemy's weapon system capability level. This discrepancy in capability will result, after months or sometimes years of requirements determination, in Class V modifications. The conceptual structure of this subsector is presented in Figure 4-9. However, during our research, we found that a majority of the Class V deficiencies were generated as a result of the technology that is available, rather than through mission area analysis (6:B-6). Therefore, included in the model is a technology availability factor to capture the actual driving force for Class V deficiencies.

Discussion of the Flow Diagrams and Equations. The flow diagram of this subsector is presented in Figure 4-10. Table 4-4 list the variables in this subsector. The DYNAMO equations are as follows:

```
L   CL5.K     = CL5.J+DT*(CL5GR.JK- CL5DR.JK)
R   CL5GR.KL = (CL5RQ.K+TECHAV.K/ADFAC.K)
R   CL5DR.KL = CL5.K/.5
```

The level of Class V capability deficiencies (CL5) is increased by two auxiliary factors, the Class V deficiencies requirement factor (CL5RQ) and the technology available factor (TECHAV). Class V deficiencies are decreased when they are released to HQ USAF for review, approval and development.

```
R   CL5GR.KL = (CL5RQ.K+TECHAV.K/ADFAC.K)
A   CL5RQ.K  = TABLE(CL5RQT,WSCD.K,0,10,2)
T   CL5RQT   = 0/1.0/1.5/2.0/2.5/3.0
A   WSCD.K   = MAX(DWSC.K - WSCL.K,0)
```

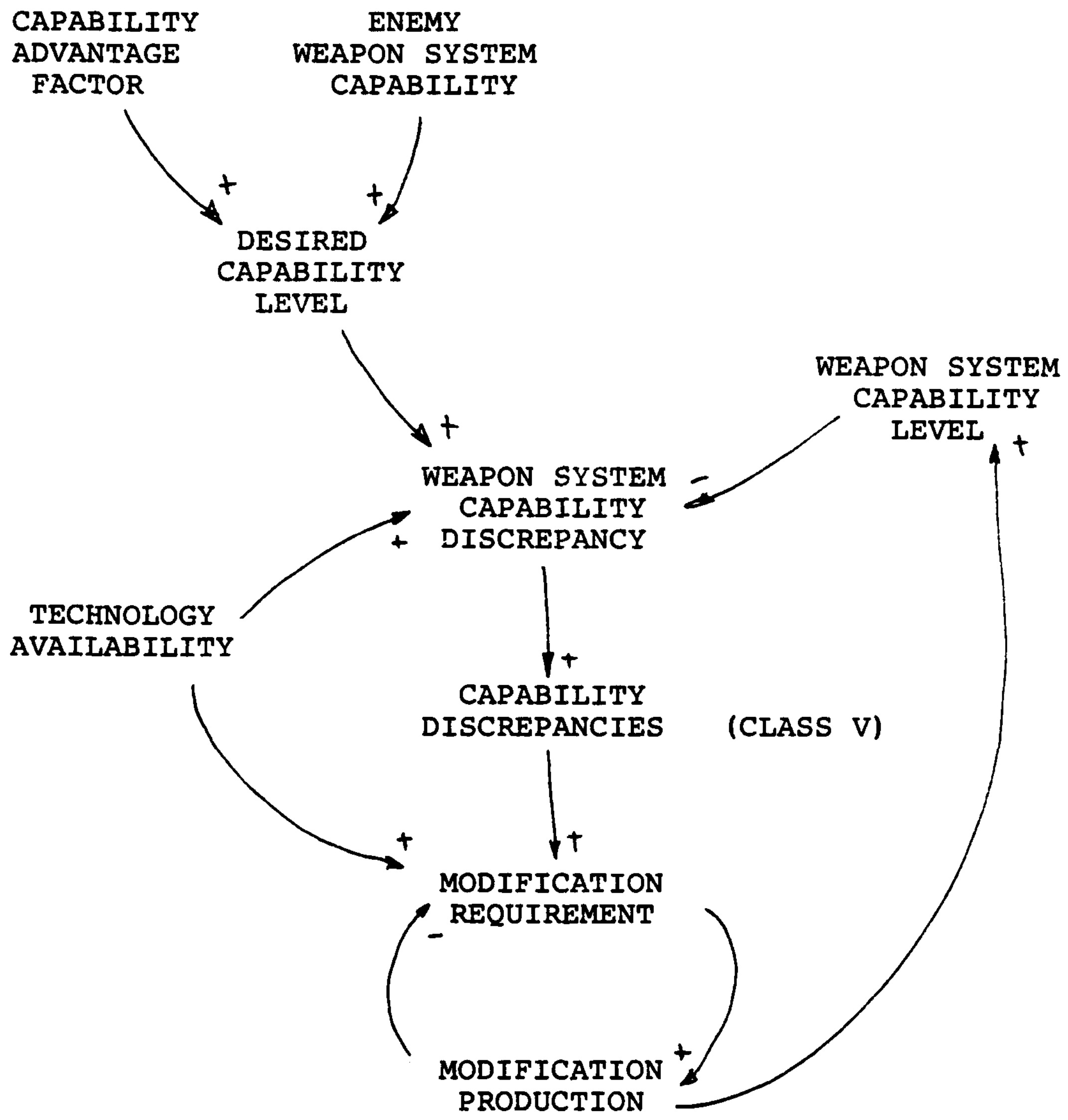


Fig. 4-9. Capability Deficiency
Causal Loop Diagram

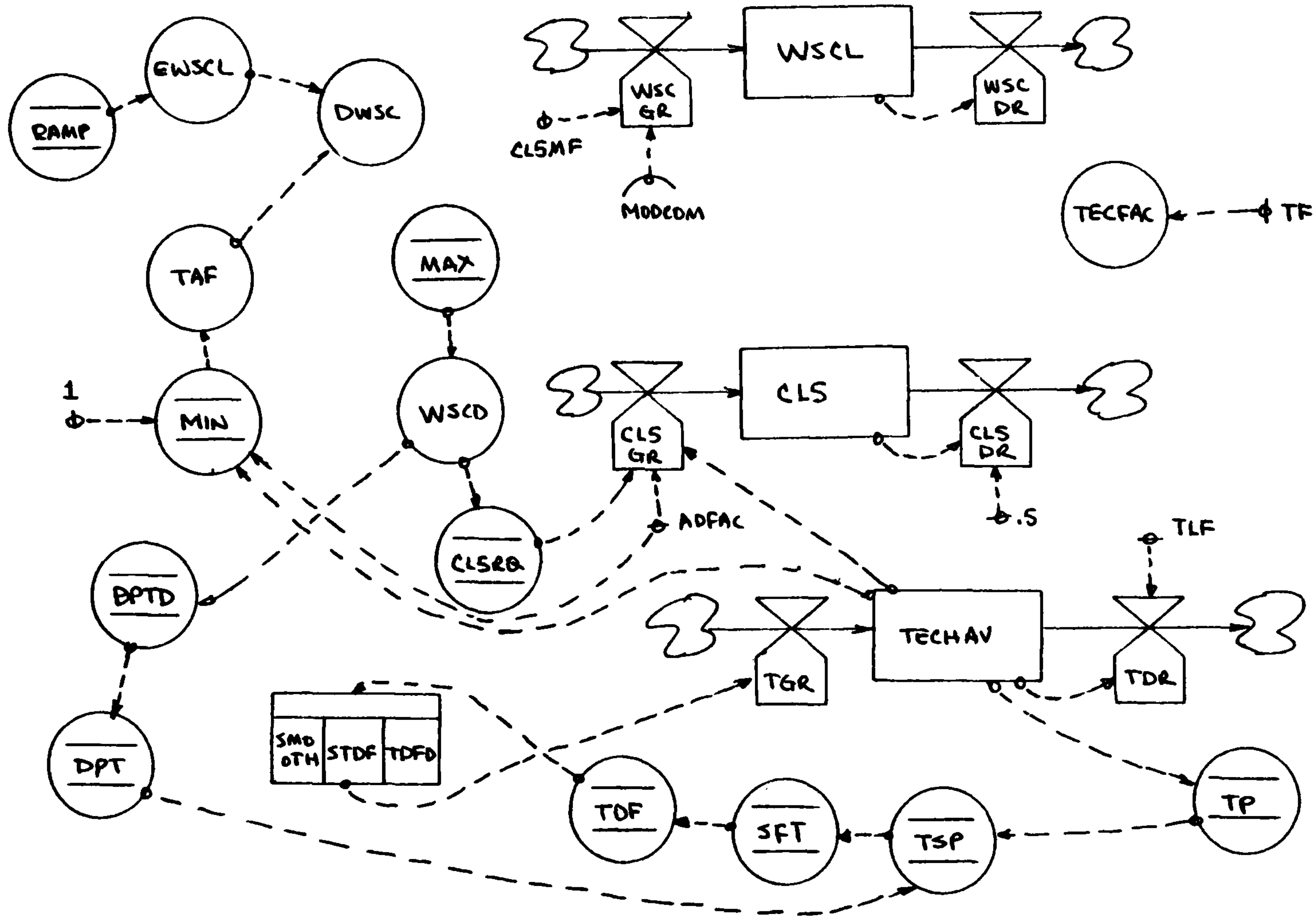


Fig. 4-10. Capability Deficiency Flow Diagram

TABLE 4-4

VARIABLES APPEARING IN FIGURE 4-10

Variable	Definition
CL5	Class V Capability Deficiencies
CL5GR	CL5 Growth Rate
CL5DR	CL5 Release Rate
CL5C	Initial Value for CL5
CL5RQ	Class V Requirements
WSCD	Weapon System Capability Discrepancy
DWSC	Desired Weapon System Capability
WSCL	Weapon System Capability Level
WSCGR	Weapon System Capability Growth Rate
WSCDR	Weapon System Capability Decrease Rate
EWSCL	Enemy Weapon System Capability Level
CAF	Capability Advantage Factor
TAF	Technology Availability Factor
ADFAC	Adjustment Factor
TECHAV	Technology Available
TGR	Technology Growth Rate
TDR	Technology Decay Rate
TDF	Technology Discovery Fraction
STDF	Smoothed Technology Discovery Fraction
TDFD	Technology Discovery Delay
SFT	Search for Technology
TSP	Total Search Pressure
TP	Technology Pressure
DPT	DOD Pressure for Technology
DPTD	DOD Perceived Technology Difference
AMPF	Amplification Factor
MODCOM	Modification Completed
CL5MF	Fraction of Production that are CL5
TECFAC	Technology Factor
TLF	Technology Loss Fraction
TLFC	Technology Loss Fraction Constant

The Class V requirement factor (CL5RQ) is determined by the weapon system capability discrepancy. The table values are derived from the yearly Class V modification requirements submitted for funding. The discrepancy level is the difference between the U.S. perceived weapon system capability level and the enemy weapon system capability level. Depending upon this level of discrepancy, the number of Class V deficiencies per period can be approximated by the table function CL5RQT.

```
L   WSCL.K   = WSCL.J+DT*(WSCGR.JK - WSCDR.JK)
N   WSCL     = WSCLC
C   WSCLC    = 5
R   WSCGR.KL = MODCOM.K(1)/FMOD.K/12.0*CL5MF.K
A   CL5MF.K  = CL5MFC
C   CL5MPC   = .30
R   WSCDR.KL = TECFAC.K*WSCL.K
A   TECFAC.K = TP
C   TF       = .01
```

The above equations describe the weapon system capability level of USAF aircraft. Capability will increase only by those Class V modifications that are completed (MODCOM). The weapon system capability growth rate (WSCGR) is determined by dividing the number of modification completed (MODCOM) by the number of modification funded (FMOD). This factor is then multiplied by the fraction of modifications that are Class V (CL5MF). The capability level is reduced by obsolescence and the technology that is available but not incorporated in the existing weapon system. The obsolescence and technology factor is represented by TECFAC, and is set to one percent of the current capability level per period. This essentially says that in about twenty years, the existing capability, without any modifications accomplished on the weapon system, will decrease to about ten percent of the current level. This hypothesis is reasonable considering the fairly rapid turnover of technology.

```
A    DWSC.K     = EWSCL.K*CAF.K*TAF.K
A    EWSCL.K    = IEWSCL+RAMP (.02,48)
C    IEWSCL     = 6
A    CAF.K      = 1.30
A    TAF.K      = MIN(1,TECHAV.K/ADFAC.K)
A    ADFAC.K    = 50.0
```

Desired weapon system capability (DWSC) is calculated by multiplying the enemy weapon system capability (EWSCL) by a capability advantage factor (20:115) and a technology availability factor (TAF). EWSCL is entered here as a ramp function, at some initial level. For the purpose of this model, EWSCL was not extensively developed and was treated as an exogenous force. Capability advantage factor (CAF) is an amplification factor that represents an approximate thirty percent desired weapon system capability advantage over the enemy. This is a fraction of capability over and above what we perceived as the current enemy capability level. TAF is a multiplier used to reduce the desired capability level when the technology is not available to achieve that level of advantage. Maximum value for TAF is one, which means we have the technology available to have a thirty percent advantage.

```
L    TECHAV.K    = TECHAV.J+DT *(TGR.JK-TDR.JK)
N    TECHAV      = TECHC
C    TECHC       = 100
R    TDR.KL      = TECHAV.K*TLF.K
A    TLF.K       = TLFC
C    TLFC        = .0167
R    TGR.KL      = TECHAV.K*STDF.K
A    STDF.K      = SMOOTH(TDF.K,TDFD)
C    TDFD        = 6.0
A    TDF.K       = TABHL (TDFT,SFT.K,0,1,.2)/12.0
T    TDFT        = .01/.03/.07/.1/.12/.13
A    SFT.K       = TABHL (SFTT,TSP.K,0,2,0,.4)
T    SFTT        = .1/.15/.32/.52/.8/1.0
A    TSP.K       = TP.K+DFT.K
A    TP.K        = TABHL(TPT,TECHAV.K,0,100,20)
T    TPT         = 1/1/.8/.5/.27/.1
A    DPT.K       = TABHL(DPTT,DPTD.K,-5.0,5.0,2.0)
```

```
T   DPTT     = .1/.15/.2/.5/.7/.9
A   DPTD.K   = WSCD.K*AMPF.K
A   AMPF.K   = AMPFC
C   AMPFC    = 1.10
```

As mentioned earlier, the avilability of technology drives the generation of Class V deficiencies. The above equations calculated the level of technology available (TECHAV) dynamically. The technology growth rate is a function of the current technology availability level and a smoothed technology discovery fraction (STDF) with a smoothing time (TDFD) of six periods or six months. This will dampen any sudden technology break-through that may occur. The technology decay or loss rate here is given a loss fraction. We assume a five-year turnover in technology and this loss per period turns out to be about .0167.

The technology discovery fraction (TDF) is determined by a table function, taking information from the level of search for technology pressure (SFT). As the pressure for technology goes up, the growth rate generally will increase. The SFT is a function of the total search pressure (TSP), which is composed of technology pressure and the DOD pressure. When the technology availability level is high, the pressure for new technology is low, and when the technology availability level is low, research and development personnel will initiate a search effort for new technology. DOD pressure arises when DOD perceives a discrepancy between its weapon systems and those of the enemy. Pressure increases as the discrepancy becomes positive and lowers when the discrepancy is negative. The discrepancy is further amplified by an amplification factor (AMPF), to represent an even greater increased pressure when a discrepancy exists.

This completes a detailed explanation of the need sector. Once discrepancies have been generated, they enter the approval process. This approval process is represented by the model's requirement sector, and will be discussed next.

Requirement Sector

The requirement sector reflects the process of determining yearly modification requirements that AFLC and HQ USAF have to process for budget purposes. The requirement sector encompasses the process of reviewing submitted deficiencies from operating commands, approving legitimate deficiencies and submitting these approved deficiencies for funding. The reviewing process starts with the receipt of the perceived deficiencies as reported by the field. This is usually in the form of a Material Deficiency Report (MDR), an accident report or potential safety report. When reports are received, the systems manager (SM) will establish a material improvement project (MIP) by tasking the responsible equipment specialist to investigate the reported deficiency. System engineers usually will carry on the investigative effort to determine if the need to modify the subsystem is valid. If it is valid, a feasibility study will be initiated to determine solutions that will correct the deficiency. This process may take about twelve months, depending on the cost to correct the deficiency. It is submitted to either the Air Logistics Center (ALC) Configuration Control Board (CCB), the AFLC CCB or HQ USAF for approval, and inclusion in the modification budget. Those deficiencies that are not approved by the SM will be returned to operating command with justification and explanation. The operating command may resubmit for reconsideration or discard the proposal.

Discussion of the Causal Loop Diagram

The causal loop diagram for this sector is in Figure 4-11. As the four different types of deficiencies increase, the level of modification requests in review increase. As the level of modification requests in review increase, the number of modifications approved increase. That, in turn, increases the total modification requirements for that fiscal year. Total modification requirements are the sum of new modification requests generated throughout that year, ongoing modifications that require further funding, and the modifications that are approved but were not funded the previous year. Ongoing modifications that require funding are those modifications that require multi-year kit purchasing and

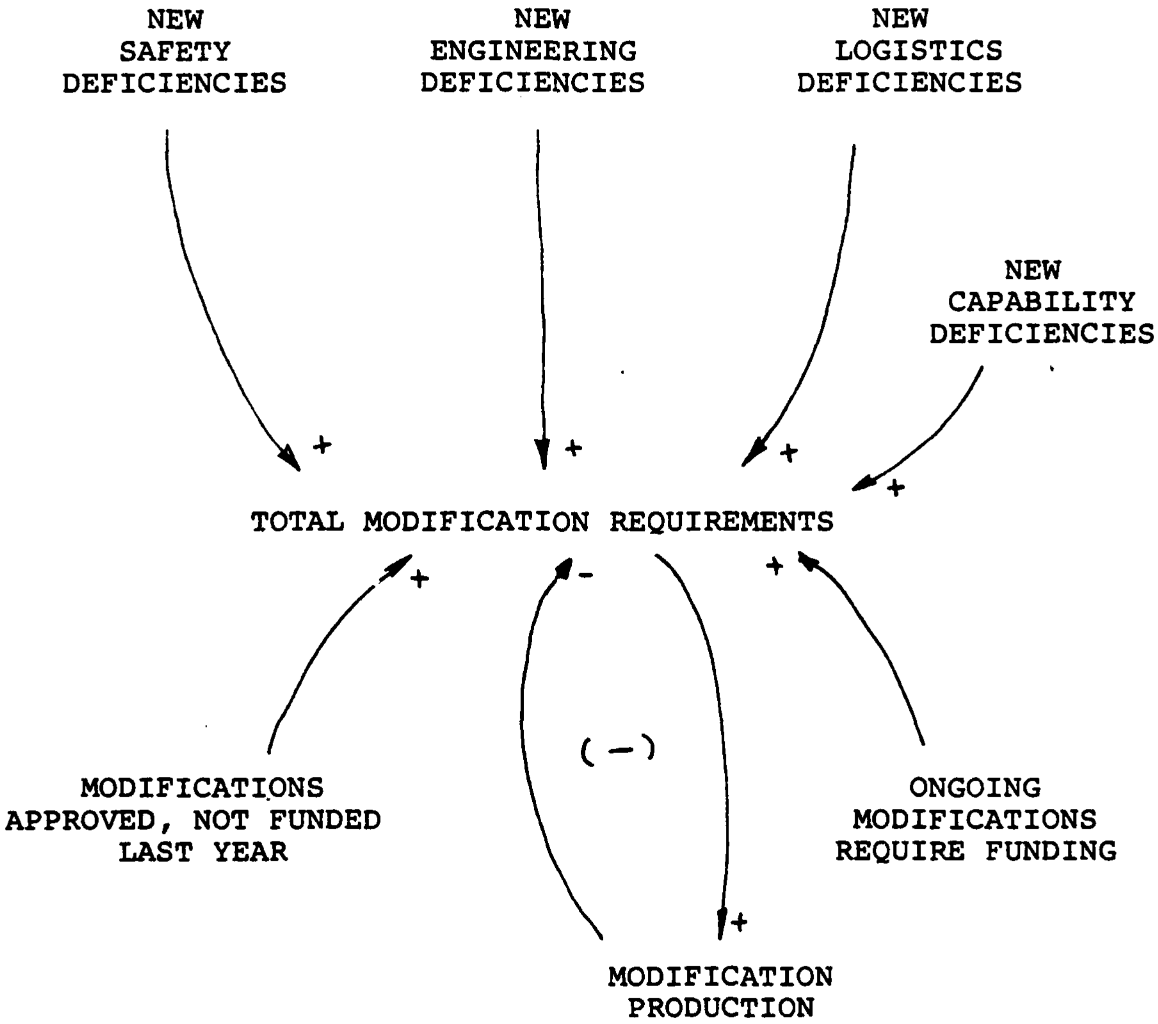


Fig 4-11. Modification Requirement
Causal Loop Diagram

installation. Modifications approved but not funded, represent those modifications that are resubmitted for funding competition.

Discussion of the Flow Diagrams and Equations

The flow diagram for this sector is presented in Figure 12 and the variables appearing in the sector are in Table 4-5. Since reviewing and approval processes differ between Class IV and Class V modifications, they are discussed separately.

The Class V modification requests, review and approval authority is solely at HQ USAF level. Class V proposed modifications are reviewed against feasibility, cost, schedule, and the risk of the new technology. Modification approval is based on these factors:

```
L   CL5RIR.K = CL5RIR.J+DT*(CL5IR.JK-CL5AR.JK)
R   CL5IR.KL = CL5.K/.5
R   CL5AR.KL = CL5RIR.K/REVT5.K
A   REVT5.K  = REVT5C
C   REVT5C   = 36.0
L   CL5A.K   = CL5A.J+DT*(CL5AR.JK - CL5AR.JK)
R   CL5RR.KL = CL5A.K/.5
```

The process, from recognition of need, to final approval of the proposed modification may take up to three years. Length of the approval process is one area of major

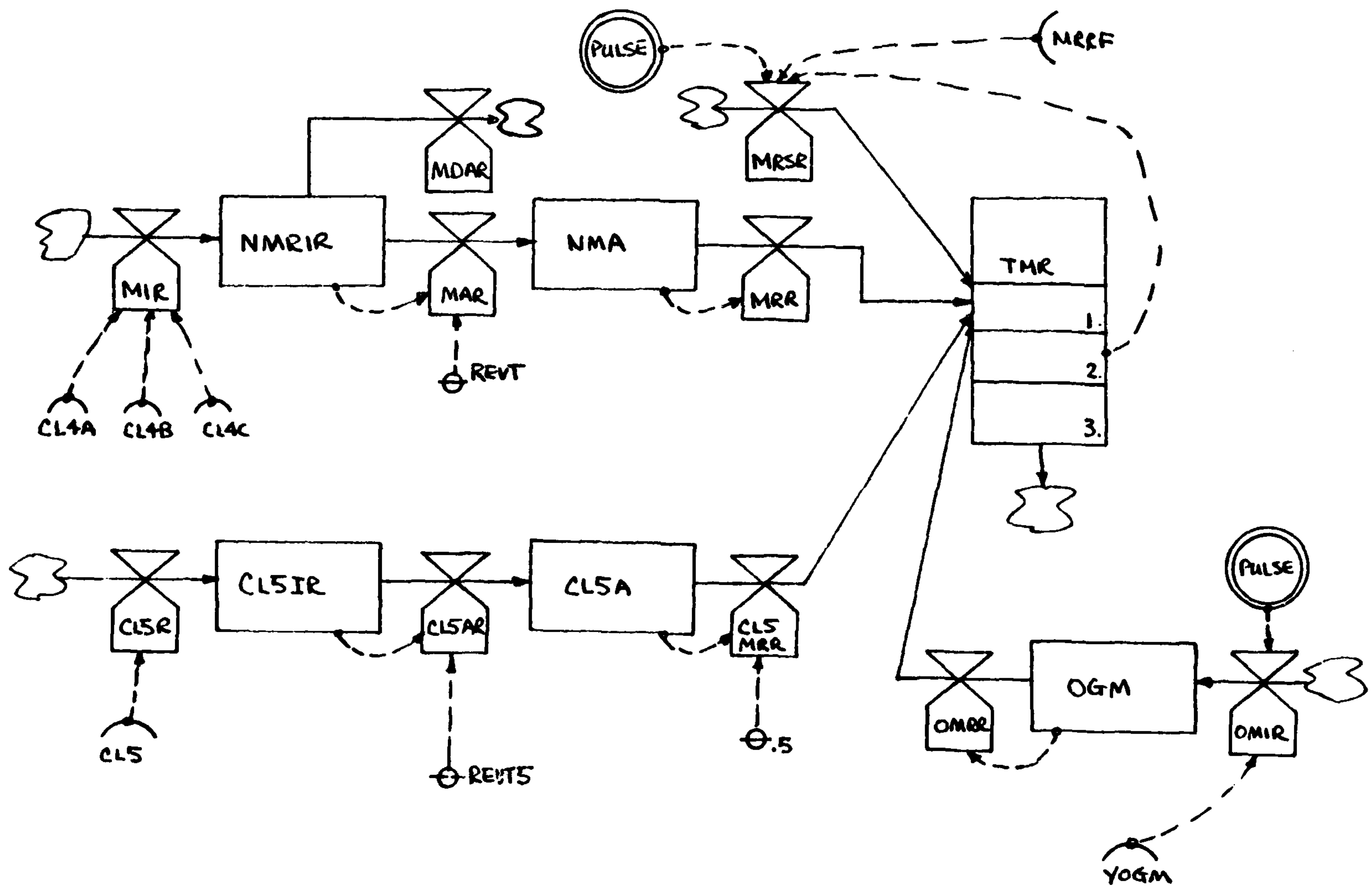


Fig. 4-12. Modification Requirement Flow Diagram

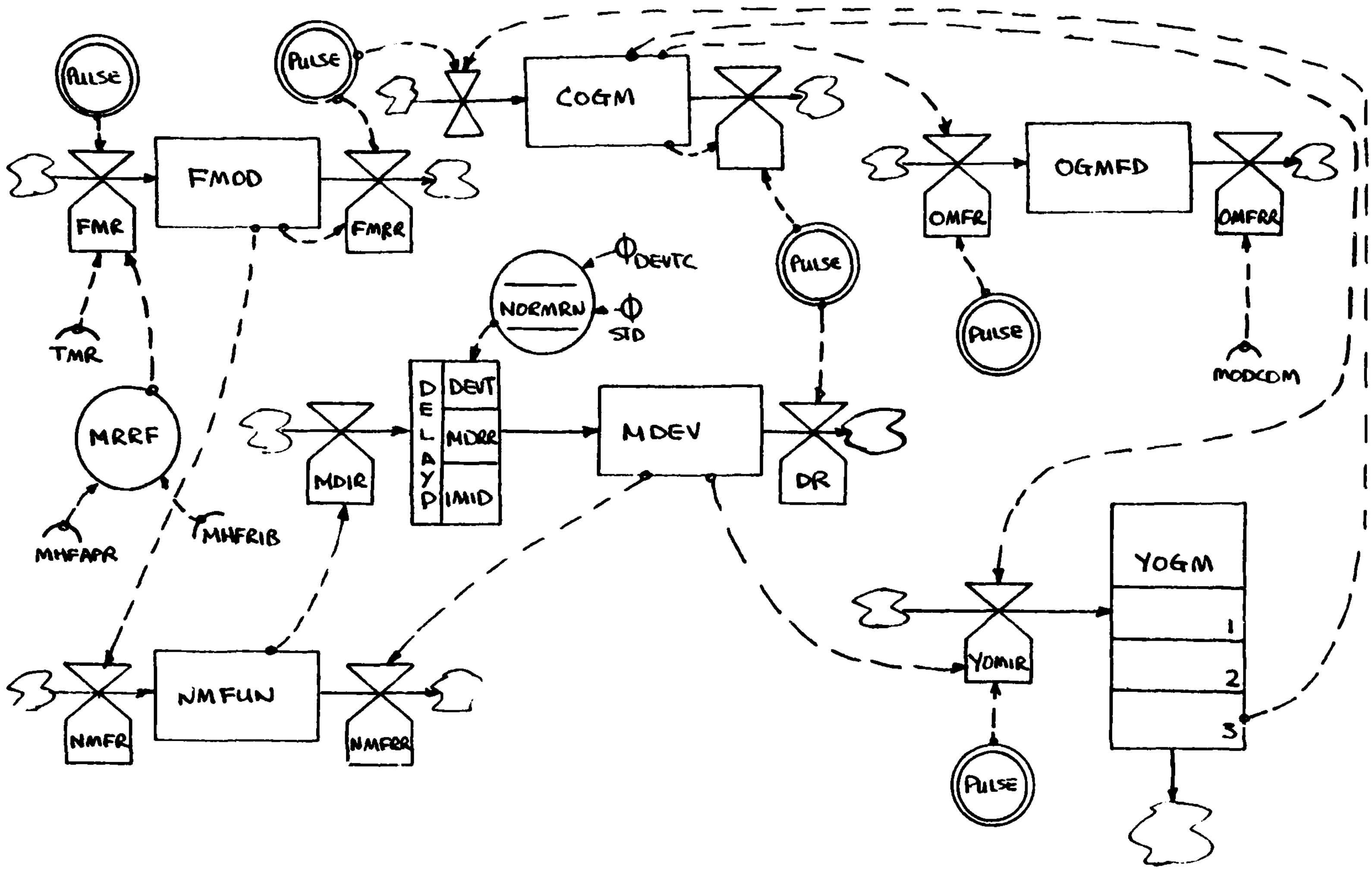


Fig. 4-12--Continued

TABLE 4-5

VARIABLES APPEARING IN FIGURE 4-12

Variable	Definition
NMRIR	New Modification Request in Review
MAR	New Modification Approval Rate
MIR	New Modification Request Input Rate
MDAR	New Modification Request Disapproval Rate
REVT	Modification Review Time
MAF	Modification Approval Fraction
NMA	New Modification Request Approved
MRR	Modification Requirement Rate
TMR	Total Modification Requirements
OMRR	Ongoing Modification Requirement Rate
MRSR	Modification Resubmission Rate
FMR	Funded Modification Rate
MRRF	Modification Requirement Reduction Factor
MHFAPR	Modification Hardware Funding Appropriated (BP-110C'
MHFRIB	Modification Hardware Funding Requested in Budget
DUMSH1	Dummy Shift Function
OGM	Ongoing Modifications Require Funding
YOGM	Yearly Ongoing Modifications Info
OMIR	Ongoing Modifications Input Rate
YOMIR	Yearly Ongoing Modifications Rate
OGMFD	Ongoing Modification Funded
CL5IR	Class V Modification Request in Review
CL5R	Class V Modification Request Input Rate
CL5AR	Class V Modification Request Approval Rate
CL5A	Class V Modification Request Approved
CL5RR	Class V Modification Requirement Rate
REVT5	Class V Modification Request Review Time
MDEV	Modification Engineering Development Completed
DUMSH2	Dummy Shift Function
NMFUN	New Modifications Funded
NMFR	New Modifications Funding Rate
NMFRR	New Funded Modifications Reduction Rate
MDEV	Modification Engineering Development Completed
YOGM	Yearly Ongoing Modifications
FMOD	Funded Modifications
OGM	Current Year Ongoing Modification
COMFR	COGM Funded Rate
OMFR	Ongoing Modification Funded Rate

TABLE 4-5--Continued

Variable	Definition
OMFRR	Ongoing Modification Funded Reduction Rate
MODCOM	Modification Completed
MDEV	Modification Engineering Development Completed
MDRR	Modification Development Completion Rate
MDIR	Modification Development Initiation Rate
DEVT	Modification Development Time
IMID	Modification Under Engineering Development
MDEVT	Mean Development Time
STD	Standard Deviation of MDEVT

criticism of the modification system (6:B-7). The major problem is the transformation from need to requirement definition. To define what is actually required to meet the need is quite a difficult task, and is the major reason it takes as long as three years to get final approval and compete for funding.

```
L   NMRIR.K = NMRIR.J+DT*(MIR.JK-MAR.JK-MDAR.JK)
N   NMRIR   = NMRIRC
C   NMRIRC  = 10.0
R   MIR.KL  = (CL4A.K CL4B.K CL4C.K)
R   MAR.KL  = NMRIR.K*MAF.K/REVT
C   REVT    = 12.0
A   MAF.K   = MAFC
C   MAFC    = .80
R   MDAR.KL = NMRIR.K (1-MAF.K)/REVT)
```

The Class IV modification request in review level is increased when the system manager receives the deficiency reports. The input rate is the sum of the three different types of deficiencies reported by the field during each period. These requests then undergo the investigative process and finally get approved or disapproved. The approval fraction (MAF) is about eighty percent. The rest will be disqualified as invalid modification requirements. The reviewing time (REVT) is approximately twelve months depending on the complexity of the modification.

```
L    NMA.K = NMA.J DT*(MAR.JK-MRR.JK)
N    NMA    = NMAC
R    MRR.KL= NMA.K
```

The level of new modifications approved (NMA) is accumulated from all the approved modifications and decreased by the modification requirement rate (MRR). When a new deficiency reaches this phase, it is ready to compete for modification funds.

```
For YR = 1,3
L    TMR.K(1)    = TMR.J(1)+DT*(MRR.JK+CL5 RR.JK+OMRR.JK
                                               + MRSR.JK)
N    TMR (YR)    = TMRI(YR)
T    TMRI (*)    = 0/443/400
R    OMRR.KL     = OGM.K/12.0
```

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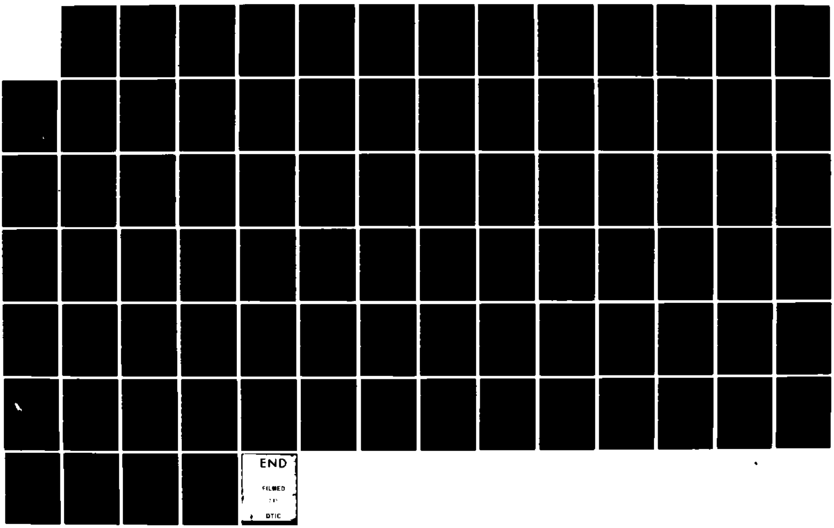

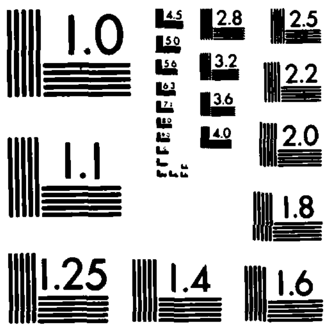

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
R   MRSR.KL = PULSE(TMR.K(2)/3*(1-MRRF.K)/DT,0,12)
A   MRRF.K  = MHFAPR.K/MHFRIB.K
A   DUMSH1.K= SHIFTL(TMR.K,INTERV)
C   INTERV  = 12
```

Total modification requirements (TMR) represent the sum of all Class IV and Class V approved modifications, all ongoing modifications that require multi-year funding, and modifications that were approved but not funded in the previous year. MRR represents the Class IV requirement rate; CL5RR is the Class V requirement rate; OMRR is the ongoing modification requirement rate; and MRSR is the modification resubmission rate.

Ongoing modifications requiring funding are about seventy percent of the previous year's ongoing modifications. The average modification is completed in approximately three years; therefore, modifications resubmitted for funding are about a third of the previous year's total modification requirement. The total modification requirement is structured in a one-dimensional array with three elements. TMR(1) is the accumulative current year modification requirement. Every June, modification requirements are submitted from the ALC system managers to AFLC/LOAP for incorporation in the fiscal year prioritization list. This list is then forwarded to HQ USAF for budgeting purposes. TMR(2) contains the total number of modification requirements put in the POM budget exercise and DOD budget. TMR(3) contains the total number of modification requirements for the funding appropriation year. The percentage of modification requirements, TMR(3) funded, depends upon the amount of modification funds appropriated that fiscal year. The Modification Requirement Reduction Factor (MRRF) is this percentage, and is calculated by dividing the total amount of BP-1100 funds appropriated, by the amount requested in the budget. BP-1100 funds are procurement funds appropriated for the purpose of procuring modification hardware, more specifically, modification kits. That factor is then multiplied by the total requirement, TMR(1), to determine the number of modifications funded (FMOD).

```
L   FMOD.K    = FMOD.J+DT*(FMR.JK-PULSE(FMOD.J/DT,
                                   12.0, YEARLY))
N   FMOD      = FMODC
C   FMODC     = 65
R   FMR.KL    = PULSE(TMR.K(3)*MRRF.K/DT,12,YEARLY)
```

FMOD is used for information purposes. It is used to calculate the number of new start modifications that have been approved and funded. The pulsing structure in the above equations is repeated throughout the model. In general, the level is increased by pulsing in the input rate, and at the end of the year, the level is totally depleted. It is then ready for another fiscal year's information. This structure is an example given by Richardson and Pugh (23:128). This structure is used frequently in the financial sector to capture the funding level at DOD and AFLC.

```
L    NMFUN.K = NMFUN.J+DT* (NMFR.JK-NMFRR.JK)
N    NMFUN   = NMFUNC
C    NMFUNC  = 10.0
R    NMFR.KL = PULSE(MAX(0,FMOD.K-YOGM.K(3))/DT,.1,YEARLY)
R    NMFRR.KL= MDEV.K/12
```

The number of new funded modifications is increased by the difference between the total number of funded modifications (FMOD), and the total number of ongoing modifications requiring multi-year funding. The pulsing structure is again used to capture the idea that information is distributed to all responsible parties. The MAX function is used here in the event that there is no new-start modifications funded. Newly funded modifications are reduced as they are put into the modification engineering development (MDEV) cycle. While in this cycle, modifications are considered to be undergoing development, testing, prototyping and trial installation (10).

```
L    MDEV.K  = MDEV.J+DT*(MDRR.JK-PULSE(MDEV.J/DT,12.0,
                                                YEARLY))
N    MDEV    = MDEVC
C    MDEVC   = 0
R    MDRR.KL = DELAYP(MDIR.JK,DEVT.K,IMID.K)
```

```
R   MDIR.KL = NMFUN.K/3.0
A   DEVT.K  = NORMRN(MDEVT,STD)
C   MDEVT   = 18.0
C   STD     = 3.0
```

After new start modifications have been approved and funded, a process of engineering development will be initiated. This effort is usually performed by the contractor in all major modifications, and is represented by the above equations. In this pipeline delay structure, modifications in development are treated as if they were goods flowing through a pipeline, and after a certain delay time, the development effort is completed. The development time is approximately eighteen months and is represented by a normal random number function (NORMRN) with a mean (MDEVT) of eighteen, and a standard deviation of 3.0. At the end of the development effort, the new start modifications will again be resubmitted for BP-1100 dollars, for kit purchasing, and O&M dollars, for the installation of kits, modification development completed (MDEV), provides information to yearly ongoing modifications that require funding, so that yearly ongoing modifications requiring funding may be included in TMR(1).

```
L   COGM.K    = COGM.J+DT*(COMFR.JK-PULSE(COGM.J/DT,0,
                                               YEARLY))
N   COGM      = COGMC
```

```
C    COGMC     = 0
R    COMFR.KL = PULSE(YOGM.K(3)/DT,.5,YEARLY)
```

The portion of funded modifications (FMOD) that are not new start modifications (NMFUN) are ongoing modifications that require further funding. This is represented by current year ongoing modifications (COGM) that are funded that particular fiscal year. This information is fed back directly into cumulative ongoing modifications that have been funded, but for which the installation of modification kits has not yet been accomplished.

```
L    OGMFD.K   = OGMFD.J+DT*(OMFR.JK-OMFRR.JK)
N    OGMFD     = OGMFD1
C    OGMFD1    = 790
R    OMFR.KL   = PULSE(COGM.K/DT,.75,12)
R    OMFRR.KL = MODCOM.K(2)/12
```

The equations above represent the cumulative ongoing modifications funded where installation has not been accomplished. If this level builds up, this represents a large number of man-hours in backlog at the ALC level. The backlog at ALC depends upon the ALC production capacity and the availability of aircraft for modification. The level of OGMFD is increased by the ongoing modification funding rate and is decreased by modifications completed (MODCOM).

```
L    OGM.K      = OGM.J+DT*(OMIR.JK-OMRR.JK)
N    OGM        = OGMI
C    OGMI       = 0
R    OMIR.KL    = PULSE(YOGM.K(2)/DT,0,YEARLY)
L    YOGM.K(1)= YOGM.J(1)+DT* (YOMIR.JK)
N    YOGM(YR) = YOGMI (YR)
T    YOGMI (*) = 0/60/50
R    YOMIR.KL = PULSE((COGM.K*.70+MDEV.K)/DT,11,YEARLY)
A    DUMSH.K    = SHIFTL(YOGM.K,INTERV)
```

OGM represents the level of ongoing modifications that require further funding and decrease when transferred into TMR (1). After OGM becomes a modification requirement, it will decrease to zero. The level of ongoing modifications will increase again at the beginning of the next fiscal year. OGM is determined by the information contained in the one-dimensional array YOGM. YOGM has three elements. Index 1 contains the number of modification engineering developments completed and about seventy percent of the current year ongoing modifications. The DUMSH 2 is used to capture the yearly information that will eventually feedback to the total modification requirement, TMR(1).

This concludes the discussion of the requirement sector. The next sector to be discussed is the financial sector.

Financial Sector

In the previous two sectors, deficiencies were generated, and through the approval process, became defined modification requirements. This sector describes the budgeting, appropriation and expenditure of modification funding. The demand for financial resources depends upon the number of approved modification requirements. There are two types of funds required for the accomplishment of aircraft modifications. They are O&M funds and BP-1100 funds. BP-1100 funds are used for purchasing of modification kits, while O&M funds are used for the installation of modification kits. Essentially, O&M funds are used to pay for labor and BP-1100 funds to pay for material.

The budgeting of O&M, or installation funds, is based upon yearly projected man-hour requirements (8). Requirements are based upon the number of expected modifications to be installed at the ALCs during the next budgeting year. The budgeting of hardware funds is completely separated and unrelated to the budgeting of installation funds (8). While installation funds are budgeted yearly, and man-hour requirements are known far enough in advance to make installation budget requests fairly stable, the hardware budgets are multi-year budgets based on the total number of modification programs approved, and are relatively unstable. Each modification program has a cost requirement. Total cost represents all BP-1100 dollars requested in the model's budget. This dual funding structure has been the subject of criticism (16:65).

The appropriation process of modification funding is similar to that of any governmental agency. When the final DOD budget, which includes the Air Force budget is received by Congress, the Congress will determine the overall spending patterns to meet national objectives (21:35). Based upon national economic conditions and various lobbying efforts, Congress will allocate to DOD, and DOD will, in turn, allocate to the Air Force, dollars, a portion of which will be spent on aircraft modifications.

Expenditure of modification funds is accomplished through payment for modification kits purchased from contractors, or manufactured organically, and for payment of modification installation activities at each of the five ALCs.

<u>Discussion of the Causal Loop Diagram</u>

A causal loop diagram of the financial sector is presented in Figure 4-13. As modification requirements increase, the modification funding requests will increase. The level of DOD-appropriated funds will increase as the support factors increase. These factors include Presidential support, Congressional support and lobbying pressure upon decision makers. These support factors increase as the

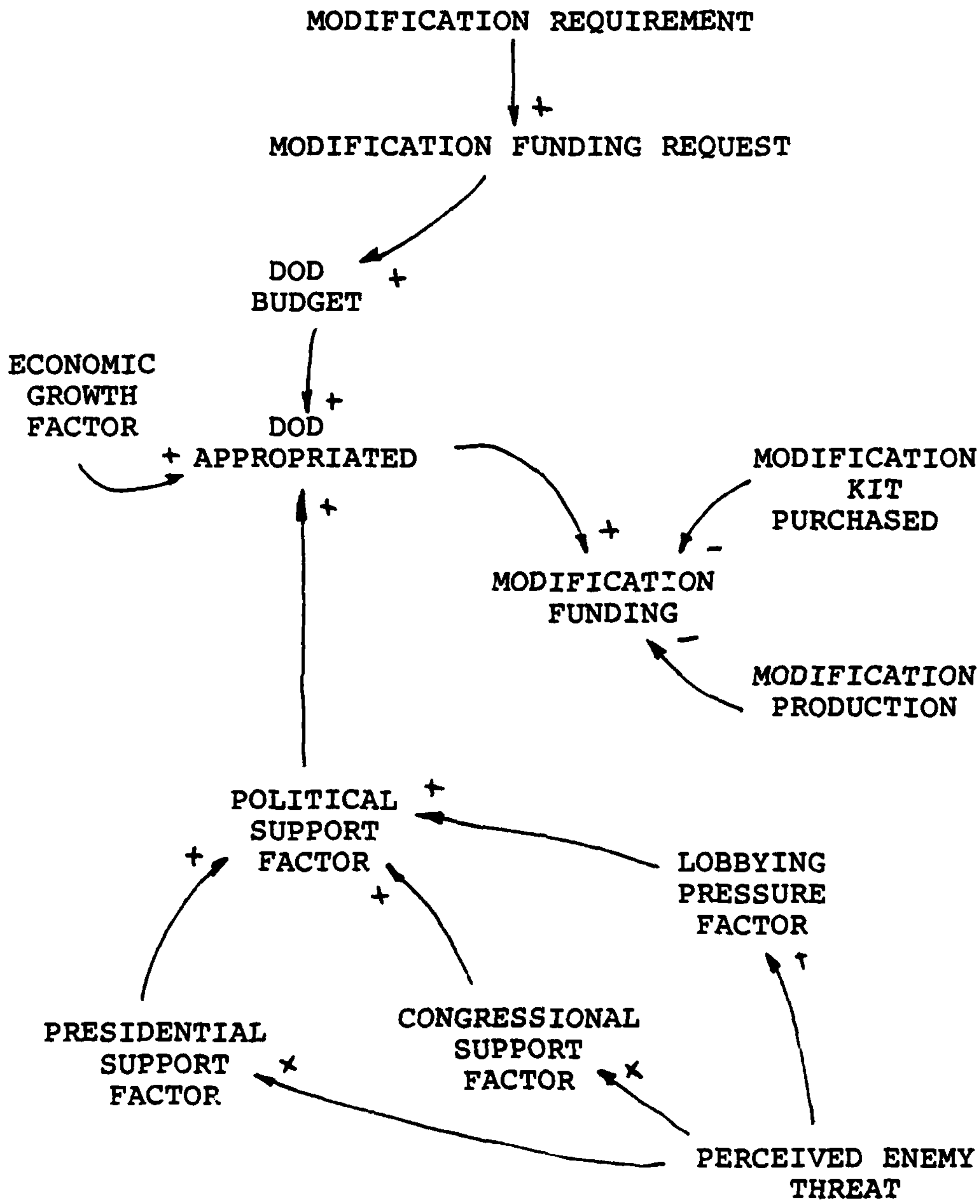

Fig. 4-13. Financial Sector
Causal Loop Diagram

perceived threat of the enemy increases. When the perceived threat to the country's national security is high, usually more dollars are made available to the DOD and less to the non-DOD sectors. When the total DOD-appropriated dollars goes up, we can generally expect the total modification dollars to go up accordingly.

Discussion of the Flow Diagrams and Equations

The flow diagram for this sector is presented in four figures, Figures 4-14 through 4-17. The following is a discussion of the DYNAMO equations that are constructed to represent the conceptual structure described earlier.

```
A    MHFREQ.K = AVMC.K*TMR.K(3)
A    AVMC.K   = AVMCC*(1+.06*(TIME.K/12.0))
C    AVMCC    = 7.0E6
```

The equations above calculated the total modification funding requirement for hardware (MHFREQ). It is determined by multiplying the average modification cost by a total number of modification requirements TMR(3). Average modification cost (AVMCC) is calculated by using the data from the FY 83 and FY 84 modification requirements priority lists submitted for budgeting. The average cost of modifications is assumed to increase with time at an inflation rate of six percent.

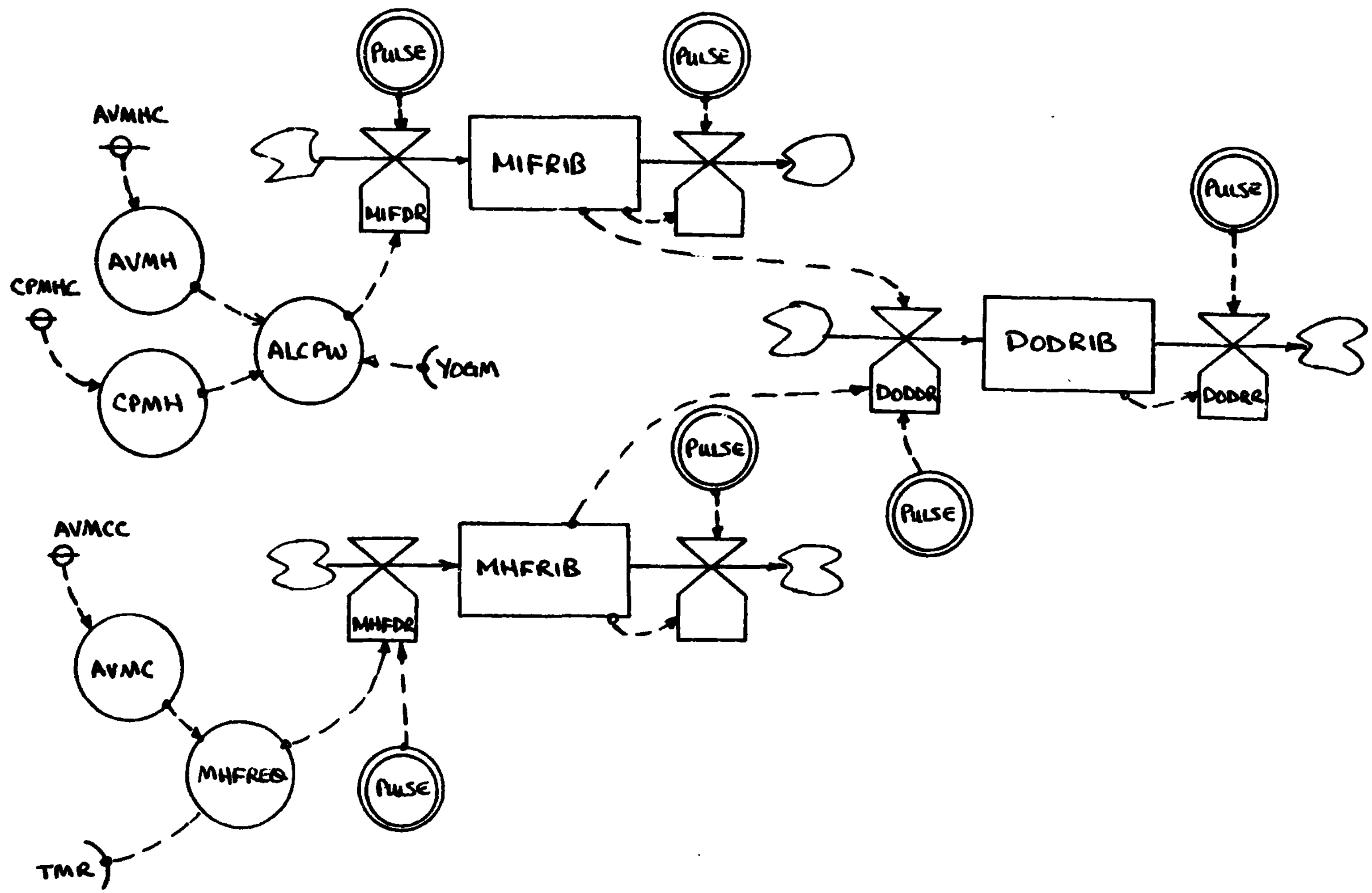

Fig. 4-14. Financial Sector (Budgeting) Flow Diagram

TABLE 4-6

VARIABLES APPEARING IN FIGURE 4-14

Variable	Definition
MHFREQ	Modification Hardware Funding Requirements
AVMC	Average Modification Cost
TMR	Total Modification Requirements
AVMCC	Average Modification Cost for FY 83 & FY 84
MHFRIB	Modification Hardware Funding Requested in Budget
MHFDR	Modification Hardware Funding Demand Rate
ALCPW	Air Logistic Centers Planned Workload
AVMH	Average Man-Hours per Modification
CPMH	Average Cost per Man-Hour
MIFRIB	Modification Installation Funding Request in Budget
MIFDR	Modification Installation Funding Demand Rate
DODRIB	DOD Funding Requested in Budget
DODDR	DOD Funding Demand Rate
DODRR	DOD Funding Demand Reduction Rate

```
L    MHFRIB.K    = MHFRIB.J+DT*(MHFDR.JK-PULSE(MHFRIB.J/
                                           DT,12.0,YEARLY))
N    MHFRIB      = MHFB
C    MHFB        = 3.1E9
R    MHFDR.KL    = PULSE(MHFREQ.K/DT,12,YEARLY)
C    YEARLY      = 12.0
```

The level of BP-1100 hardware budget request (MHFRIB), is based on the total modification hardware funding requirement (MHFREQ). It is pulsed into the system every fiscal year and pulsed out at the end of the fiscal year.

```
A    ALCPW.K     = YOGM.K(3)*AVMH.K
A    AVMH.K      = AVMHC
C    AVMHC       = 60E3
L    MIFRIB.K    = MIFRIB.J+DT*(MIFDR.JK-PULSE(MIFRIB.J/
                                           DT,12.0,YEARLY))
N    MIFRIB      = MIFB
C    MIFB        = 6.37E7
A    CPMH.K      = CPMHC
C    CPMHC       = 15.0
R    MIFDR.KL    = PULSE(ALCPW.K*CPMH.K/DT,12,YEARLY)
```

The modification installation funding requirement (MIFRIB), is based on yearly ongoing modifications that require further funding, times the average man-hours per modification. Average man-hours per modification. Average man-hours per modification is calculated based on the number of modifications submitted and approved, and the total number of man-hours involved in the accomplishment of these modifications (2,3).

```
L   DODRIB.K    = DODRIB.J+DT*(DODDR.JK-DODRR.JK)
R   DODDR.KL    = PULSE(MHFRIB.K+MIFRIB.K)/DT,12.25,
                                              YEARLY)
N   DODRIB      = MHFB+MIFB
R   DODRR.KL    = PULSE(DODRIB.K/DT,12.25,12)
```

When all the budgeting information is compiled and documented, it is submitted to DOD for incorporation into the overall DOD budget and, in turn, into the President's budget. Budget information required for the DOD-level budget is comprised of a modification hardware budget and a modification installation budget. The DOD budget level is used to determine how much DOD will get. Historically, DOD does not get all it asks for, and the amount it does receive is based on the different support factors discussed earlier.

The flow diagram for the appropriation phase is contained in Figures 4-15 and 4-16. The equations are presented below:

```
L   GNP.K       = GNP.J+DT*(GNPGR.JK)
N   GNP         = GNPI
C   GNPI        = 2858.6E9
```

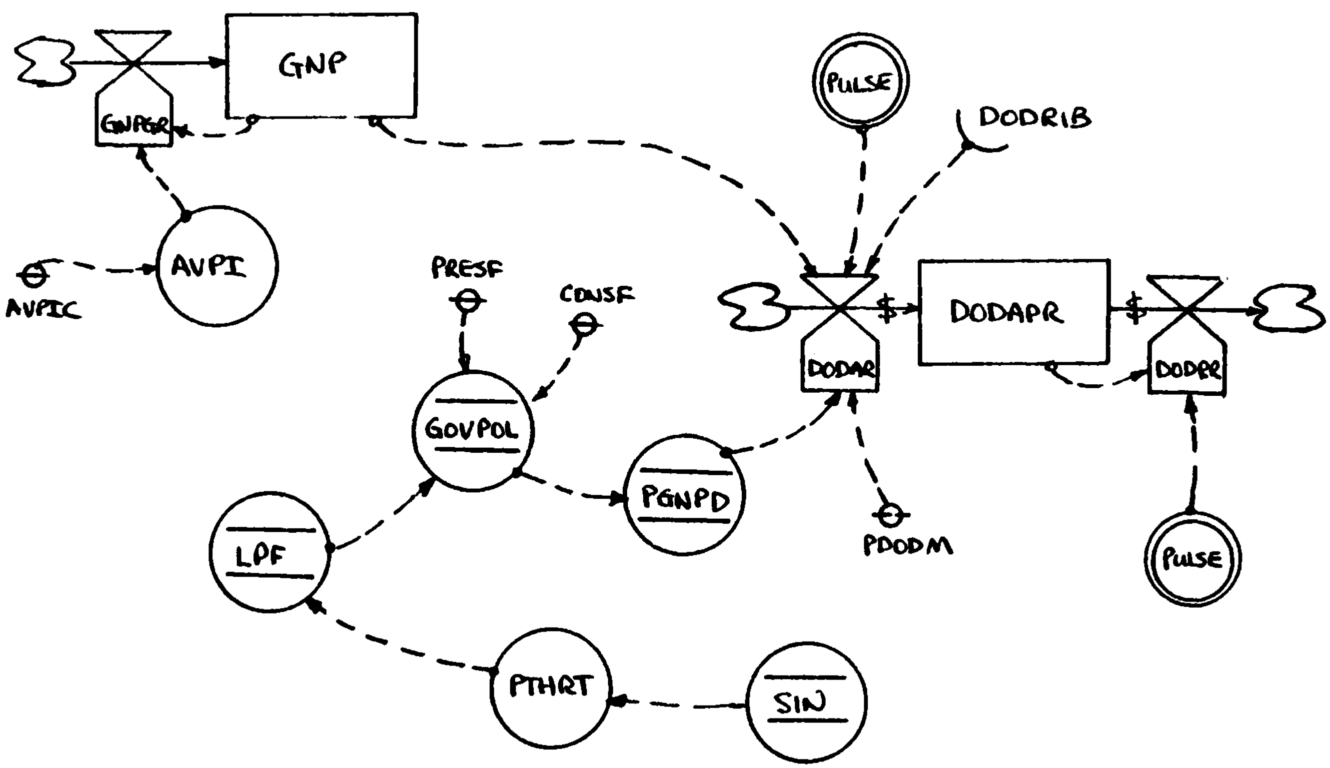

Fig. 4-15. Financial Sector (Appropriation) Flow Diagram

TABLE 4-7

VARIABLES APPEARING IN FIGURE 4-15

Variable	Definition
GNP	Gross National Product
GNPGR	GNP Growth Rate
AVPI	Average Annual Percentage of Increase of GNP
DODAPR	DOD Funding Appropriated
DODAR	DOD Funding Appropriation Rate
PGNPD	Percent of GNP to DOD
PDODM	Percent of DOD Funding to Modification
GOVPOL	Governmental and Political Factor
DODRIB	DOD Funding Requested in Budget
PRESF	Presidential Support Factor
CONSF	Congressional Support Factor
LPF	Lobbying Pressure Factor
PTHRT	Perceived Threat of Enemy
MIFXR	Modification Installation Funding Expenditure Rate

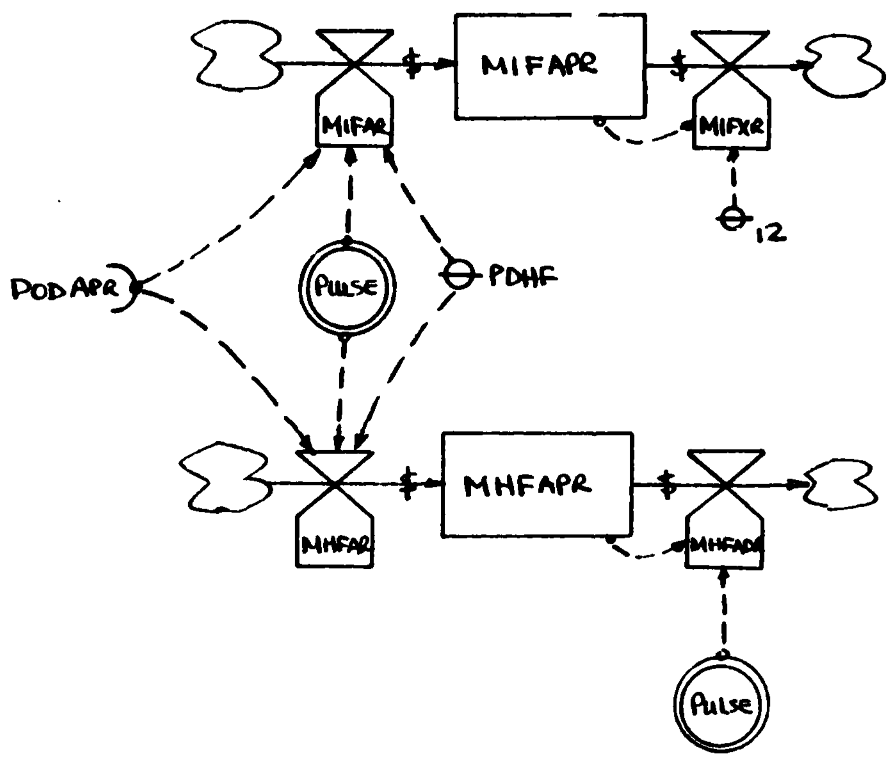

Fig. 4-16. Financial Sector (Appropriation)

TABLE 4-8

VARIABLES APPEARING IN FIGURE 4-16

Variable	Definition
MIFAPR	Modification Installation Funding Appropriated
MIFAR	Modification Installation Funding Appropriation Rate
MHFADR	Modification Hardware Funding Appropriated Decrease Rate
MIFXR	Modification Installation Funding Expenditure Rate
MHFAPR	Modification Hardware Funding Appropriated
PDHF	Percent of DOD Funding to Hardware Funding
DODAPR	DOD Funding Appropriated

```
R    GNPGR.KL = AVPI.K/12*GNP.K
A    AVPI.K   = AVPIC
C    AVPIC    = .109147
```

The amount of DOD dollars appropriated is dependent upon several factors. One of these factors is the economic condition of the country. The economic condition of a country is usually measured in terms of its gross national product (GNP), that is, the total goods and services produced during a particular year (14:5-8). GNP is included here as information to determine the number of DOD dollars it may be allocated. The trend of growth of nominal GNP was determined by averaging the last ten years data (9:89).

```
L    DODAPR.K  = DODAPR.J+DT*(DODAR.JK-PULSE(DODAPR.J/
                                        DT,4.0,YEARLY))
N    DODAPR    = 0
R    DODAR.KL  = PULSE(MIN(GNP.K*PGNPD.K*PDODM.K,
                             DODRIB.K)/DT),OCT,YEARLY)
C    OCT       = 4.0
A    PGNPD.K   = TABLE(PGNPDT,GOVPOL.K,.5,1.5,.2)
T    PGNPDT    = .05/.055/.06/.07/.08/.09
A    PDODM.K   = PDODMC
C    PDODMC    = .013
```

The level of DOD-appropriated dollars (DODAPR) is increased when Congress passes the appropriations bill and the President allocated the appropriated dollars to DOD.

It should be pointed out that DODAPR is only representing DOD dollars for modification purposes--that includes the two different types of funds discussed before. DODAPR is determined by comparing what DOD has requested in the budget, to what is available to DOD. What is available to DOD, is determined by the percentage of GNP that will go to DOD (PGNPD). The percentage of DOD dollars to modifications (PDODM), will determine how many dollars are available for aircraft modifications. The percentage of GNP that goes to DOD is determined by Government and political pressures, and PDODM is entered here as a constant. This is calculated from several years of data (9:80). The PGNPD table was constructed based on the minimum percentage DOD had gotten, approximately five percent of GNP, and the upper value of about nine percent. These are normal peacetime percentages of GNP usually devoted to DOD.

```
A    GOVPOL.K    = (PRESF.K+CONSF.K)*LPF.K
A    PRESF.K     = PRESFC
C    PRESFC      = .5
A    CONSF.K     = CONSFC
C    CONSFC      = .5
A    LPF.K       = TABLE(LOBBY,PTHRT.K,0,1.0,.2)
T    LOBBY       = 1/1/1.1/1.2/1.3/1.4
A    PTHRT.K     = .5+.5*SIN(6.283TIME.K/48)
```

The Government and political pressure (GOVPOL) is a measure of support from the President (PRESF) and the Congress (CONSF). This support factor is further modified by the level of lobbying effort (LPF). This model assumes that the President and Congress stay in the neutral position (a value of .5). That means no bias toward either DOD or non-DOD. The lobbying pressure factor is a table function based on the perceived threat. Generally speaking, as the perceived threat increases, DOD's lobbying pressure increases; and as DOD's lobbying pressure increases, DOD dollars will increase. The above equations capture this idea.

```
L    MHFAPR.K    = MHFAPR.J+DT*(MHFAR.JK-PULSE(MHFAPR.J/
                                         DT,4.0,YEARLY))
N    MHFAPR      = MHFC
C    MHFC        = 1.7E9
R    MHFAR.KL    = PULSE(DODAPR.K*PDHP.K/DT,4.25,YEARLY)
A    PDHF.K      = PDHFC
C    PDHFC       = .75
```

Once DOD appropriations have been determined, they are further divided between hardware and installation appropriations. The fraction that goes to hardware (PDHF) is approximately seventy-five percent. This is pulsed into the yearly appropriated BP-1100 fund. The other twenty-five percent goes to (O&M) funds for distribution and expenditures (20).

L MIFAPR.K = MIFAPR.J+DT*(MIFAR.JK-MIFXR.JK)

N MIFAPR = MIFA

C MIFA = 0

R MIFAR.KL = PULSE(DODAPR.K(1-PDHF.K)/DT,4.25,YEARLY)

R MIFXR.KL = MIFAPR.K/12.0

These equations represent the portions of modification funds that go to installation. The structure is a rather simple one. The ALC modification manager has a fairly accurate prediction of his workload. The money appropriated usually is depleted at the end of each fiscal year to pay for the services done by production workers. The expenditure of the BP-1100 fund is more complicated and is addressed next.

The expenditure structure of the BP-1100, or modification hardware funding is presented in Figure 4-17.

The level of MHFAPR is pulsed into the pot of modification hardware funds available (MHFA). MHFA is the accumulated BP-1100 money that was not obligated in previous years. BP-1100 dollars are three-year obligatory dollars. If this yearly appropriated money is not used, it builds up in this level and indicates a number of modifications are having scheduling problems, such as modification kit production problems, kit delivery problems, etc.

L MHFA.K = MHFA.J+DT*(MHFTR.JK-MHFOR.JK)

N MHFA = MHFAC

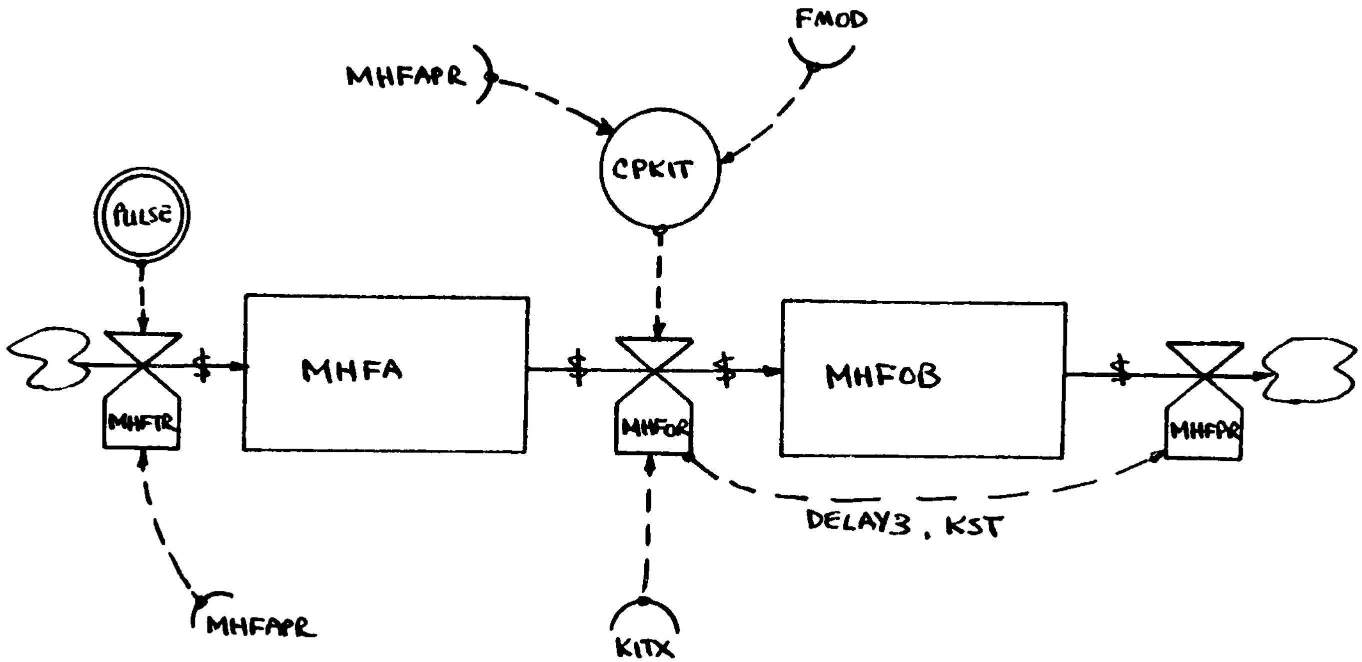

Fig. 4-17. Financial Sector (Expenditure) Flow Diagram

TABLE 4-9

VARIABLES APPEARING IN FIGURE 4-17

Variable	Definition
MHFA	Modification Hardware Funding Available
MHFTR	Modification Hardware Funding Transfer Rate
MHFOB	Modification Hardware Funding Obligated
MHFOR	Modification Hardware Obligation Rate
MHFPR	Modification Hardware Payment Rate
KST	Kits Shipment Time Delay
KITX	Kits in Transit to Depot
CPKIT	Cost Per Kit
FMOD	Funded Modifications

```
C    MHFAC    = 4.25E8
R    MHFTR.KL= PULSE(MHFAPR.K/DT,4.5,YEARLY)
R    MHFOR.KL= KITX.K* CPKIT.K/DT*CLIP(1,0,MHFA.K,
                                  KITX.K*CPKIT.K/DT)
A    CPKIT.K = MHFA.K/FMOD.K
```

The yearly modification hardware funding transfer rate is the amount appropriated each year (MHFAPR). The obligation rate (MHFOR) is dependent upon the number of modification kits that have been ordered and are being shipped to the modification center. The cost per kit (CPKIT) times the number of kits on order, represents the number of dollars to be obligated. A clip function is used to insure that funds cannot be over-obligated. This is a general requirement for all Federally-funded projects. The cost per kit is calculated by dividing MHFAPR by the FMOD, the number of funded modifications.

```
L    MHFOB.K    = MHFOB.J+DT*(MHFOR.JK-MHFPR.JK)
N    MHFOB      = MHFOBC
C    MHFOBC     = 0
R    MHFPR.KL   = DELAY3(MHFOR.JK,KST,K)*CLIP(1,0,MHFOB.K,0)
```

As funds are obligated, this increases the level of modification hardware funds obligated. This level is depleted as contractors are paid for the goods and services provided. The payment rate (MHFPR) is represented by a third order delay, and the delay time is the kit shipment time. Contractors are usually paid after the modification kits are on hand at the ALC modification center, and have been verified for their completeness. The amount paid out cannot exceed the available funds obligated. This is represented by the CLIP function as shown above.

This completes the discussion of the modification financial sector. With the availability of both BP-1100 and O&M funds, the last stage of the modification system will be activated. This is the production sector and will be discussed next.

Production Sector

The purpose of the production sector is to combine modification kits, financial resources and labor, to produce more reliable, maintainable and capable weapons systems. This last stage of the system represents actual installation of modifications. The last three sectors have established the need, defined the requirements, and obtained the financial resources in order that this last stage of work can be carried on. Modification installation is usually performed at Air Logistics Centers in conjunction with regularly programmed depot maintenance (PDM). During PDM, the aircraft is stripped for numerous inspections, overhauling and general maintenance. This makes the installation of most major modifications relatively easier to perform.

Within AFLC, there are five Air Logistics Centers which are assigned different series of aircraft for management, maintenance and modification. The production capacity of the five ALCs is the modification production constraint (8). The production capacity determines the number of aircraft that each center can handle during any time of the year. Aircraft are scheduled in, by tail number, for PDM, at which time modifications are installed (8). The rate of modification production is largely determined by the aircraft cycle time (8). Cycle time is determined by the aircraft fleet size and the space available for these aircraft. If space is not a constraint, then aircraft theoretically can be modified in a fairly speedy manner. The production capacity is determined in this model by two major factors: the level of production workers and the level of production space. The other constraints are kit availability and aircraft availability from the operating command.

Discussion of the Causal Loop Diagram

The causal loop diagram is presented in Figure 4-18. The conceptual structure of this sector is a rather simple one. There are several factors that have an effect on the modification production: the number of modification kits on hand, the availability of production workers, and the availability of production space. As these factors increase, modification production increases. This structure is similar

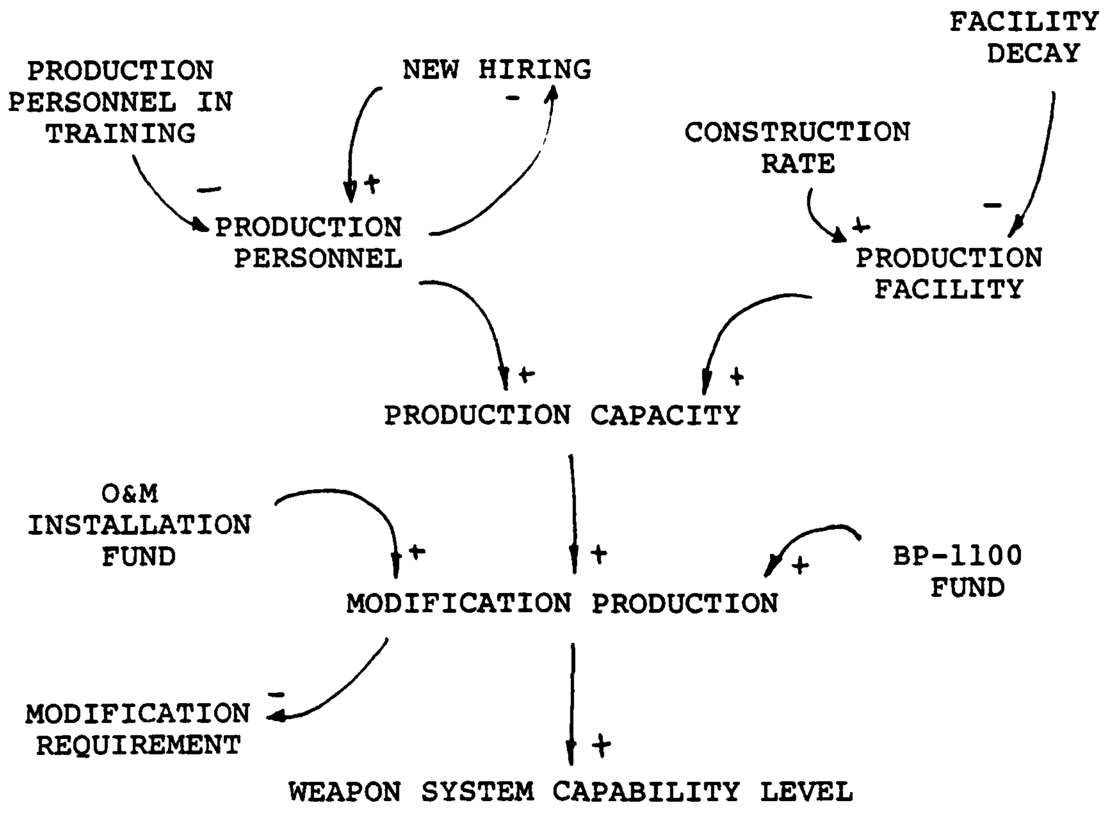

Fig 4-18. Production Sector
Causal Loop Diagram

to any production structure where demand and resources available drive the production rate and level of production output (14:155-159).

<u>Discussion of the Flow Diagram and Equations</u>

The flow diagram of this sector is presented in Figure 4-19. The equations for this sector are presented below:

```
L    MODCOM.K(1)  = MODCOM.J(1)+DT*(MPCR.JK)
N    MODCOM(YR)   = MODC(YR)
T    MODC(*)      = 0/50/50
A    DUMSH7.K     = SHIFTL(MODCOM.K,INTERV)
R    MPCR.KL      = DELAYP(MPIR.JK,PRODT.K,MODIW.K)
A    PRODT.K      = NAC.K/LOPS.K*ADJF.K
A    NAC.K        = 8600.0
```

The variable completed modifications (MODCOM) is set up as an array to capture yearly modifications completed. This information is used to reduce the level of ongoing modifications that were funded during the beginning of the fiscal year, and also used to increase the weapon system capability level. Modification production is structured as a pipeline system to capture the delay involved with installation modifications. The production time is a function of the level of production space (LOPS), the number of aircraft needed to be modified (NAC), and the number of aircraft

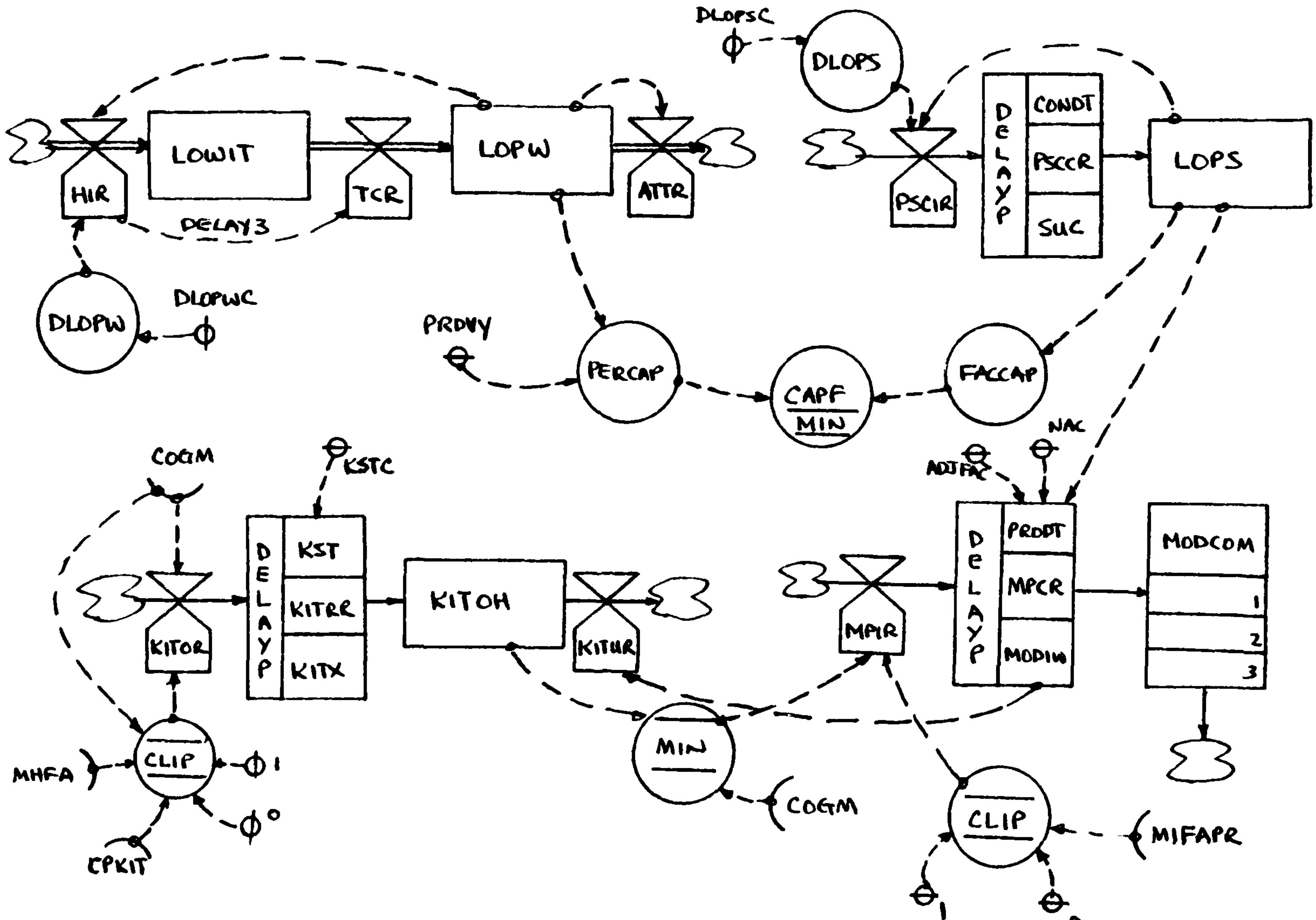

Fig 4-19. Production Sector Flow Diagram

TABLE 4-10

VARIABLES APPEARING IN FIGURE 4-19

Variable	Definition
MODCOM	Modification Completed
MPCR	Modification Production Rate
MPIR	Modification Production Initiation Rate
PRODT	Production Delay Time
NAC	Total Number of Aircraft
ADJF	Adjustment Factor
MODIW	Modification in Work
KITOH	Level of Modification Kits on Hand
KITRR	Kits Receiving Rate
KITUR	Kits Use Rate
KST	Kits Shipment Time
KITX	Kits in Transit
COGM	Current Year Ongoing Modifications
MHFA	Modification Hardware Funding Available
CPKIT	Cost Per Kit
CAPF	Production Capacity Factor
MIFAPR	Modification Installation Funding Appropriated
PERCAP	Personnel Capability
PROVY	Productivity of Workers
FACCAP	Facility Capability
LOPS	Level of Production Space
PSCCR	Production Space Construction Completion Rate
PSCIR	Production Space Construction Initiation Rate
CONDT	Construction Delay Time
SUC	Space Under Construction
LOPW	Level of Production Workers
TCR	Training Completion Rate
HIR	Hiring Rate
LOWIT	Level of Worker in Training
DLOPW	Desired Level of Production Workers
LOPW	Level of Production Workers
ATTR	Attrition Rate

the modification centers can handle (ADJF). The fewer the aircraft needing modification, the shorter the time required to finish the modification of the whole fleet. As more production space is made available, the production time is also shortened. The average modification takes about three years to complete.

```
R   MPIR.KL   = MIN(COGM.K,KITOH.K)/12.0*CAPF.K*CLIP
                                        (1,0,MIFAPR.K,0)
A   CAPF.K    = MIN(PERCAP.K,FACCAP.K)
A   PERCAP.K  = LOPW.KPRDVY.K
A   PROVY.K   = PRDVYC
C   PRDVYC    = 1.0
A   FACCAP.K  = LOPS.K
```

The modification production input rate decision (MPIR) is based on two sources of information: the number of modifications that are funded and ongoing, and the number of modification kits on hand. The number of modification installations that can be initiated, is determined by the minimum of the two factors: required number of kits on hand and production line capacity. Included in the rate equation is the factor of MIFAPR. This is to assure that O&M funds are available prior to installation of the modification.

The capacity factor (CAPF) is used to determine the number of modifications that can be started. The capacity factor is a MIN function of personnel level and facility or space level. A policy change in availability of space must be accompanied by a change in the level of personnel in the same direction, otherwise there will be an excess of either people or space. This is why the capacity structure is set up as a MIN function.

Personal capability (PERCAP) is a function of the level of production workers and the workers' productivity. The product of these two factors will be a measure of the actual workers available.

Facility capability is a measure of the level of production space available for production lines. As mentioned earlier, if more space is made available than the ALC currently possesses, the modification production rate will increase.

```
L   KITOH.K  = KITOH.J+DT*(KITRR.JK-KITUR.JK)
N   KITOH    = KITOHC
C   KITOHC   = 20.0
R   KITRR.KL = DELAYP(KITOR.JK,KST.K,KITX.K)
A   KST.K    = KITC
C   KITC     = 3.0
R   KITOR.KL = (COGM.K/12.0)*CLIP(1,0,MHFA.K,COGM.K/
                                        12.0*CPKIT.K)
R   KITUR.KL = MODIW.K/DT
```

The number of kits on hand (KITOH), affects greatly the rate that modifications can be completed. Therefore, it is included here for possible investigation, once the model has been validated. The number of kits on hand is increased after kits are ordered and received at the modification center. Generally, modification kits are ordered as BP-1100 dollars are appropriated. The kit order rate is determined by need or demand. This demand information comes from the current year ongoing modification (COGM). Provided there is enough modification hardware funding available, kits can be ordered. The shipment time of kits are critical to the initiation of modification production. It is, therefore, an issue for detailed study. The kits usage rate (KITUR), is determined by the number of modifications in work (MODIW). The faster the modification production is completed, the faster the level of kits on hand is depleted through the kit usage rate.

```
L   LOPW.K   = LOPW.J+DT*(TCR.JK-ATTR.JK)
N   LOPW     = LOPWC
C   LOPWC    = 1.0
R   TCR.KL   = DELAY3(HIR.JK,3.0)
R   ATTR.KL  = LOPW.K*PATT.K
```

The above equation represents the level of production workers (LOPW) at any point in time. This level of workers affects production capacity. LOPW represents proficient workers who can work on a modification installation. This level is increased by training new hires, and is decreased by layoffs, retirements and transfers. It is included here for possible future study.

```
L   LOWIT.K  = LOWIT.J+DT*(HIR.JK-TCR.JK)
N   LOWIT    = LOWITC
C   LOWITC   = 0
R   HIR.KL   = (DLOPW.K-LOPW.K)/3
A   DLOPW.K  = DLOPWC
C   DLOPWC   = 1.0
```

The level of workers in training (LOWIT), is determined by the hiring rate (HIR) and the training completion rate (TCR). Hiring rate policies are determined by differences between the desired level of production workers (DLOPW) and the current level of production workers (LOPW). Training completion rate is a third order delay of the hiring rate, with a delay time of three months.

```
L   LOPS.K   = LOPS.J+DT*(PSCCR.JK)
N   LOPS     = LOPSC
C   LOPSC    = 1.0
R   PSCCR.KL = DELAYP(PSCIR.JK,CONDT.K, SUC.K)
R   PSCIR.KL = MAX(DLOPS.K-LOPS.K,0)
A   DLOPS.K  = DLOPSC
C   DLOPSC   = 1.0
A   CONDT.K  = 48.0
```

The level of production space (LOPS), is important to modification production as previously mentioned. It is structured as a pipeline of facility construction. High level managers may make policy decisions to erect more hangars and facilities. This would allow more aircraft to be modified at one time, thus, shortening aircraft cycle time to depot. Shortening aircraft cycle time between depot visits would help decrease modification installation backlog.

Summary

In keeping with the system dynamics approach to problem-solving, an aircraft modification model was explained in this chapter. This formulated model is composed of four major sectors, and a detailed discussion of each was presented. Chapter V will present conclusions and some recommendations for further study that evolved from this research effort.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Introduction

The general objectives of this research were to develop a conceptual understanding of the complex, dynamic nature of the modification process, and develop a computerized policy model which reflects the structure of the process. This chapter will summarize research results regarding these specific objectives. The chapter will conclude with a section recommending areas for further research.

Summary

Objective 1: Identify the structure of the modification process.

This objective was met by an extensive literature review of current Air Force regulations, previous studies and interviews with various modification managers. The research effort regarding this objective resulted in a conceptual model of the aircraft modification system structure, as shown in Figure 4-1. The system structure was first described by four sectors: need, requirement, financial and production. This macro view of the structure was further refined into subsectors for a more detailed understanding of the process.

Objective 2: Isolate the interactions and influence of the components and variables within the system.

This objective was met by translating the conceptual understanding of the system structure into causal loop diagrams. These causal loop diagrams hypothesized the pair-wise causal relationships between system variables that formed the system structure. The causal loop diagrams helped visualize the effect of a change in one variable on the system or sector qualitatively.

Objective 3: Describe the decision structure that determines the information, funding and material flows within the system.

This objective was met by the development of flow diagrams of the four sectors. These flow diagrams described in more detail the relationship between variables. Specifically, the rate in which variables flow from one level to another. The rate at which the levels increased and decreased formulated the decision structure.

Objective 4: Construct a mathematical model which represents the components, relationships, information flows and decisional policies of the system.

This objective was met by translating the flow diagram into mathematical equations which represented the hypothesized relationships and decisional structure qualitatively. The equations developed were compatible with DYNAMO simulation language. This served as a basis to accomplish Objective 5.

Objective 5: Develop a computerized model which can be used for policy analysis and development.

This objective was partially met by developing equations for all four sectors. These equations, operating together, formed a computerized model of the system. In its current form, it cannot be used for policy analysis. This will be discussed in light of the next objective.

Objective 6: Verify and validate that the model represents the structure and decision-making process within the modification process.

This objective was partially met. Validation and verification, as discussed in Chapter III, are an integral part of model development. As each relationship was hypothesized, it was evaluated based on the reasonableness of the hypothesis, and the contributing value of this relationship to the operation of the system. In many instances, originally selected variables were discarded and new variables substituted to enhance the value of the model. The computerized model should be operated as a whole, and validation testing of model structure continued, so confidence in the model can continue to grow.

Objective 7: Identify areas of sensitivity or critical issues in the modification policy.

The objective was partially met. Sensitivity analysis was not accomplished. Sensitivity analysis involves varying system parameters and observing the effect of system behavior. This should be accomplished after overall model validation has been achieved.

One critical issue was identified during the course of the research. The issue involved management's policy toward modification man-hour backlog. Man-hour backlog represents modification man-hours of approved and funded modifications that have not been installed in the involved mission designated series (MDS) aircraft. Research showed the backlog of man-hours for F-4s exceeded five million man-hours as of June 1982, while A-10's backlog was over one million man-hours. The modification manager, being interviewed, indicated that these backlogs really do not present a problem, as all required modifications available for a particular aircraft are accomplished on that aircraft each time it cycles through the depot. However, even if no new modifications were approved for installation as of now, the present size of the F-4 backlog is so great, that it would take four to six years before the system could reduce the backlog to near zero. As of this writing, there appears to be no formal policy to address the problem of backlog. Managers may want to consider the backlog to be more than just a simple catch-up problem. The problem with delayed installation of backlogged modifications raises a question concerning the value of these modifications in terms of lost capability as they go uninstalled. The amount of backlogged man-hours should carry more weight in the approval of new modifications. This would necessitate a policy change in the approval process.

Objective 8: Suggest changes, if required, in the management stucture of the modification process.

No experimentation was done with the computerized model. The experimentation should be done after sufficient confidence has been built in the model.

Recommendations for Further Research

1. The operation of the model is recommended in order to analyze the behavior of the system over time.

2. Validation of the system behavior through comparison of simulated behavior with actual historical trends is also recommended.

3. Research should be conducted to confirm the structure of the table functions in this model.

4. Policy experiments should be developed in the area of the time involved with the whole process, production facility policies and backlog policy.

5. A long-term commitment to the continual development of and expansion of this model is urged so that it may realize its full potential as a policy analysis tool.

Conclusion

The presentation of this research has indicated that the aircraft modification system is indeed a complex system. The total research effort was extremely rewarding. Although the operation of the model was beyond the scope of this research, a thorough understanding of the modification system was attained. It is hoped that this thesis will arouse certain enthusiastic modelers to continue the research from where this effort ended.

APPENDICES

APPENDIX A

MODIFICATION CLASSIFICATION AND APPROVAL AUTHORITY

TABLE 2

MODIFICATION CLASSIFICATIONS AND APPROVAL AUTHORITY

RULE	A If a Mod	B and	C Then it is	D And the approving authority is (see note 1)
1	A temporary removal of installed equipment	the removal is required to perform a temporary special mission or purpose	a Class IA Mod (see note 2)	the MAJCOM, contingent on receipt of engineering approval from the AFLC SM or IM.
2	A temporary installation of, or change to, equipment to provide an increased capability for temporary special mission or purpose	AFLC-approved installation engineering is available to accomplish it, necessary equipment can be obtained from USAF stock or command resources without additional acquisition to replenish supply, and no technical data or logistic support is needed	a Class IB Mod (see note 2)	the MAJCOM, contingent on receipt of engineering approval from the AFLC SM or IM.
3	Temporary and required to support research, development, design change, test and evaluation programs, Demonstration and shakedown operations (DASO) for Ballistic missiles, or in-service testing of systems or equipment	is needed under AFR 80-14 to conduct research and development testing. (see note 3)	a Class II Mod	AFSC for engineering approval and the MAJCOM for implementation.
4		is needed to conduct operational testing and evaluation (see note 3)		AFSC or AFLC for engineering approval, according to which command has PMR and the MAJCOM for implementation.

5		PMRT to AFLC has occurred and engineering evaluation or in-service testing is needed.		AFLC
6	To correct a test revealed deficiency which meets the definition of a Class IVA or B mod (previously known as an "update" mod to an in production configuration baseline)	PMRT from AFSC to AFLC has not occurred.	a Class III Mod (see notes 4 & 6)	HQ USAF or AFSC(see note 4 & 6). Do not use term "update" mod -- refer to this as a Class III mod.
7	To correct material deficiencies (TO-00-35D-54) required to ensure safety of personnel, system or equipment	PMRT to AFLC has occurred and if uncorrected, the hazard would ground the system or equipment, restrict flight or ground operations, or result in unacceptable risk to personnel (see note 5).	a Class IVA Modification	HQ USAF or AFLC (see note 6)
8	necessary to correct a service revealed material deficiency including one that affects reliability and maintainability (AFRs 80-5 and 66-30) electromagnetic compatibility (AFR 80-23), or communications security (AFM 100-21)	PMRT to AFLC occurred and if uncorrected the deficiency would cause mission failures, impede the system or equipment mission accomplishment, or impede mission accomplishment of other systems or equipment within the defense or civilian community	a Class IVB Mod	HQ USAF or AFLC (see note 6)
9	Needed for logistic support purposes in lieu of new acquisition.	PMRT to AFLC occurred and one of the following benefits will result: (a) improved maintainability or service life; (b) improved logistic support; (c) reduced costs, (includes standardization equipment configuration)	a Class IVC Mod	HQ USAF or AFLC (see note 6)

10	To provide a new or improved operational capability or to make permanent a Class IB modification	is needed to accomplish or enhance an assigned mission that cannot be accomplished with the present configuration	a Class V Mod	HQ USAF. Submit SON IAW AFR 57-1. NOTE: No SON needed if conditions of note 7 are met. Otherwise, AFR 57-1 applies.
11	To remove an existing capability that is no longer needed (or to make permanent a Class IA mod)		a Class V Mod	HQ USAF. NOTE: No SON is needed if conditions of note 7 are met. Otherwise, AFR 57-1 applies.
12	To enhance operational safety	provides a safety related capability not previously available as Class IV mod. Approved by AFISC.	a Class V Mod	HQ USAF. MAJCOM or AFISC to submit SON per AFR 57-1

NOTES:

1. Send requests to modify operational support aircraft to HQ USAF/LEY according to paragraph 2h.

2. The mod must permit return of the CI to original configuration within 48 hours, except for call up of the Reserve Forces. Do not delete removed equipment from DD Form 780, Aircraft Inventory Record; removed equipment must be retained (not returned to stock). Return the CI to its original configuration immediately when the requirement no longer exists, when necessary to accomplish a permanent mod, or before transfer to another command (unless the gaining command concurs in transfer of the specific configuration, appropriate records, and removed equipment). The Class IA and IB mod may be regarded as a temporary Class V mod needed to perform a temporary special mission, function or purpose and requires no logistics support (technical data or spares). It is not a substitute for a Class IV mod nor for timely submission under AFR 57-1. If permanent retention is desired, submit the requirement under Rule 10 or 11. Class I mods are always treated as mods regardless of when they occur. Obtain any required AFSC support or approval through AFLC. For joint AFLC/AFSC testing, AFSC has engineering approval authority.

3. If AFLC has PMR, coordinate with the appropriate AFLC IM or SM by sending them a copy of the Class II mod package (not applicable to AFSC test bed aircraft).

4. A Class IV mod exists only when PMR has transferred to AFLC. Before such transfer, define and treat as Class III all mods meeting criteria of Class IV Mods or Component Improvement Programs (CIPs). The AFSC program office or HQ USAF/RDP approves Class III mods (see note 6 below).

a. Include the following data in the proposed mod:

(1) Acquisition and mods to support equipment.

(2) Supporting computer programs, and computer programs which accomplish support equipment functions. NOTE: Software and software changes should be funded per AFM 172-1, paragraph 10-83, and figure 10-3.

(3) An evaluation of an early need for training equipment required to support a changed basic CI or its components.

(4) Training equipment, STDs and STD changes in the proposed mod. (Use QMC procedures to implement training equipment and simulator changes, if appropriate.) Each mod must be approved with the basic change and be available to support the basic CI mod schedule.

b. Mods to support equipment that require additional mods in the basic system, system components, or computer programs to maintain compatibility are approved only when critical for safety or mission accomplishment. The CCB approves those changes only after determining their impact on affected CIs and establishing a positive program to retain compatibility with the basic system or system components.

c. Substantiate approval and funding of Class III mods by a fully documented review of contractual alternatives.

5. Classify as Class IVA those which correct a deficiency which has caused an accident or serious incident.

6. HQ USAF/RDP and LEY must approve all Class III and IV mods respectively if the total cost exceeds $10M for aircraft or missiles or exceeds $2 million for ground equipment.

7. If the mod will result in new operational capability or is to make a Class IA or IB Mod permanent and:

(1) is less than $2M total cost for aircraft, missiles and STDs or $1M for ground equipment; and,
(2) meets Rule 3 of Table 1; and,
(3) no R&D funding (appropriation 3600) is required, no SON is needed.

Under these conditions, MAJCOMS will use AF Form 1067 for submittal to HQ USAF/XOOI, info copies to AF/RDQM and LEYY and the appropriate ALC and HQ AFLC. If the requirement is approved by HQ USAF, the approval will be by message and direct AFLC to assign a Class V mod number and prepare and submit an MPA (AF Form 2612 only) to AF/XOOI, info AF/RDQM/LEYY. Such mods should be listed separately on the MAJCOM's Class V mod list and must be briefed to the Priority Review Group (unless waived by AF/XOOI) for priority and funds competition. Implementation may be by an appropriatly coordinated HQ USAF message in lieu of a PMD.

APPENDIX B

CLASS IV AIRCRAFT MODIFICATION
KEY STEPS

Class IV Aircraft Mod Key Steps

OPCOM	1. Analyzes the assigned mission to determine the aircraft's ability to perform the tasks and functions needed to achieve the mission objectives. Submits Class IV A and IV B mod requirements to the applicable ALC for review and integration in the budget cycle.
AFLC and ALCs	2. Does analysis to find projected deficiencies, obsolescence, technological opportunities to reduce overall costs.
ALCs	3. Prepares and establishes MIP according to AFLCR 66-15.
ALCs	4. Accomplishes any preliminary engineering required to scope the problem and determines the estimated costs for submission in the budget cycle.
ALCs	5a. Prepares forms 775 according to direction in AFR 27-8. Concepts of full funding and production kit lead time away must be complied with.
	5b. Assure that proposed installation schedules are as outlined in the applicable PDM schedule.
	5c. Assure that support equipment, spares, software, and installation funds are programmed. Portrayal of these funds on the 775 is for visibility purposes only and does not assure funds availability.
	5d. Assure that weapons system trainers are programmed with the modification to the weapon system. Coordinate all proposals with the simulator SM and appropriate OPCOM.
ALCs and OPCOMs	5e. Conduct annual priority reviews by individual weapon system.
ALCs	5f. Send 775s to AFLC for review and integrated prioritizing.

AFLC/LO	6. Review 775s for accuracy and completeness. Prepare integrated Class IV priority list. Send 775s and priority list to AF/LEX/LEY.
Deputy for Avionics (aircraft only)	7. Review avionics mods to Control reduce proliferation and assure latest technology is used in avionics acquisitions.
HQ USAF/LEYY/LEXM/LEYW	8a. Reviews 775s for accuracy and completeness.
	8b. USAF/LEYY/LEXM prepare final priority list and publish the document.
	8c. USAF/LEYY/LEXM/LEYW in conjunction with XO and RD prepare the FY(XX) budget input. Class IV mods compete with Class III and V mods for the total P-1100/P-2100 funding. The mod budget then competes for funding within the total Air Force budget.
HQ USAF	9a. USAF/LEXM/LEYY/LEYW prepare the POM requirements based on the previous years unfunded mods, known new requirements which have surfaced during previous year, and the AFSC/AFLC POM submissions.
	9b. USAF BP-1100 Program Review Group integrates Classes III, IV, and V mods needs and prepares the proposed requirements list (POM), (aircraft only).
	10. The POM is worked through the program review committee, and the Air Staff board structure to determine the proposed funding level in the FY program. After submission to the Office of the Secretary of Defense (OSD), several other repetitions follow before dtermining final budget levels for the coming FY.
HQ USAF	11 and 12. USAF/LEXM prepares the Class IV portion that is based on the published priority list. Another review is conducted in OSD during the budget estimate submission (BES) cycle to obtain the FY President's

budget submission.

ALCs

13a. Prepare AFLC Form 48 according to AFLCR 57-21 in order to completely definitize the mod proposal.

NOTE: AFLC Forms 48 are normally prepared after mods are programmed but can be prepared along with 775s or in advance of the budget cycle depending upon the urgency of the requirement.

13b. ALC CCB reviews all proposed mods. The ALC CCB provides final approval for those mods under $2M and sends other approved mods to AFLC CCB for further processing.

13c. Requests funds from AFLC/LOA for approved Class IV mods.

OPCOMs

14a. Coordinate on the proposed mod.

14b. Assure that weapon systems are available to meet the proposed installation schedule and meet mission requirements.

AFLC

15a. Reviews and approves or disapproves mods over $2M and under $10M.

15b. Sends Form 48 to USAF/LEY for final approval on mods costing more than $10M.

15c. Request mod acquisition funds from USAF/LEX for programmed mods with total cost of less than $10M.

15d. Sends approved, but unprogrammed, mods with a total of less than $10M to USAF/LEY for possible sources of funds when the mod priority dictates immediate action.

HQ USAF

16a. USAF/LEYY/LEYW keep priority list of approved but unfunded mod requirements.

	16b. USAF/LEXW funds unprogrammed mod requirements if fallout funds are available based on a LEUU/LEYW priority list.
HQ USAF	17. USAF/LEY provides PMD approval and guidance on all Class IV mods over $10M.
	18. Prepares implementing PMD for Air Force directed mods.
HQ USAF	19a. USAF/LEXW issues program authority for mod acquisition funds. The program authority specifies the quantity of kits to be procured in the applicable FY.
	19b. HQ USAF/ACB issues the budget authority.
	19c. The PA and BA are the only documents which authorize funds expenditures for this purpose. The PA authorizes the program. The BA transmits actual obligation authority from HQ USAF.
AFLC	20a. Manages funds for Class IV mods.
	20b. Provides funds to the SM or IM after mod approval.
	21a. Prepares necessary documentation for acquisition efforts.
	21b. Acquires necessary kits and material to accomplish mod. Ensures that support equipment, spares, trainers, etc., are acquired in time for first kit delivery.
ALC	22a. Manages installation program.
	22b. Performs kit proofing.
ALC	23. Reports mod status through the GO-79 system.

APPENDIX C

CLASS V AIRCRAFT MODIFICATION
KEY STEPS

CLASS V MODS PROCESS

OPCOM	1. Submits statement of operational Need (SON) as outlined in AFR 57-1, updated by AF/RDQ letter 20 August 1981.
Other Commands and HQ USAF	2a. Review and comment on SON as outlined in AFR 57-1.
	2b. AFLC or AFSC provides solution alternatives with BCI and proposed PDP.
ALC/Product Division	3a. For Class V mods to CIs for which AFLC has PMR, and ALC SMs prepare BCI and submit to AFLC.
	3b. For Class V mods to CIs for which AFSC still has PMR, the product division SPO/project officer prepares BCI and submits to AFSC and the SON originator.
HQ USAF, RD Action Officer	4. After user submits revised SON with program and PDP, obtains final AFSC/AFLC and Air Staff coordination, and, prepares Form 79, Requirement Summary.
HQ USAF, RD Action Officer	5a. Presents SON and proposed Class V mod program, using AFHQ Form 79, to the RRG.
	5b. Recommends that the SON and program for solution be validated or returned to originator. If validated, recommends submission to the PRG for prioritization for funds competition.
	5c. Publishes PMD validating SON or returns SON to originator.
	5d. If a Justification for Major System New Start (JMSNS) per DoD 5000.1 is needed, process remains the same. Further programming action for FY "New Start" cannot continue

until a JMSNS has been submitted with the Air Force POM and approval by SECDEF in the Program Decision Memorandum (PDM). See DoDD 5000.1.

HQ USAF, RRG

6. The Requirements Preview or Assessment Group, through the director level RRG, validates the need and approves the Class V mod solution, a new development program, or off-the-shelf acquisition. Validation allows the program to compete for funds. Where and how the solution competes for funds within the PPBS depends on the type of program validated. If no additional study, research, or advanced development is needed, the program will enter competition for engineering development (6.4 PE's) and/or production funds (B and C). If a 6.1, 6.2 or 6.3 (technical base PE's) effort is required, the SON must compete for these funds (Go to A).

HQ USAF RRG

7. If the validated need solution approach does not require a technical base effort, but does need engineering development (6.4 PE) the program must enter competition for engineering development funds and acquisition funds simultaneously (B and C). We do not normally do engineering development until acquisition funds are included in the Air Force Program (FYDP) . If no engineering development is needed, the mod can compete directly for acquisition funds (C).

HQ USAF, RD
Action Officer

8. The validated program competes for development funds. If only a small effort is required, and it can be done with available funds, the decision can be made by the RD director responsible for the existing program. If a large effort is required, the program must compete in the PPBS for inclusion in the POM through the appropriate panel. Block 8 could consist of no more than a discussion with a 6.3 program

	element monitor or could consist of the full PPBS. At the end, either funds are available or they are not. If no funds are available, the program can continue to compete for two full budget cycles.
HQ USAF, RD Action Officer	9. If the program is still unfunded after two budget cycles, it is again reviewed by the PRG for return because its priority has not been high enough to merit initiating it within current funding constraints.
HQ USAF, RD PEM	10. If funds are available, the PMD directing the RDT&E program is issued.
HQ AFSC, SYSTO	11. HQ AFSC issues a Form 56 directing the program.
AFSC, System Division or Laboratory	12. The appropriate organization within AFSC conducts the development effort and responds with the directed product, usually including a BCI and PMP for subsequent portions of the program. If further 6.1, 6.2 or 6.3 effort is needed, the program enters again at A. If it is now ready for engineering development, it moves to B and C simultaneously.
HQ USAF, PEM	13. The Program Element Monitors (PEMs) present their proposed programs (Program Decision Packages (PDPs)) to the Air Staff Board Panels. The panels prepare proposed mission area programs for the current POM.
HQ USAF, RD Action Officer	14. Class V mods are presented both to the panels and to the PRG by the RD OPR. The PRG prepares priority lists of the mods which are approved by AF/XOO.
HQ USAF, PRG Chairperson	15. The priority lists are provided to the PRG which prepares the proposed mod program portion of the current POM effort.

HQ USAF, AF/LEXM, Panel Chairpeople, PRG Chairperson	16. The proposed mission area (Panel) programs and the PRG are presented to the PRC which integrates them into the POM and briefs the POM through the Air Force board structure for approval (normally three exercises).
HQ USAF	17. The POM is submitted to OSD and approved by the APDM after issues are resolved.
HQ USAF, RD Action Officer	18. The budget estimate submissions (BES) are now prepared based on the APDM. The PRG reviews all new start Class V mods included in the APDM. The MRG reviews the final mod budget. The process translates the POM into a current year President's budget and next FYDP.
HQ USAF, OSD, OMB, Congress	19. The budget goes through the approval and appropriation process. If R&D is required, the funds will not be included in the program for a subsequent year (FYDP).
	20. If funds are available for R&D, go to D. If not, the program can compete again. If unfunded after two cycles, it goes to C for return. If included in the APDM and achieves initial funding, the mod must compete in each subsequent PPBS cycle until it is completely funded.
	21. If mod funds are appropriated or available within the current program, go to E.
HQ USAF, RD Action Officer	22. The RD PEM prepares the PMD directing engineering development, coordinates it with appropriate Air Staff offices and has it signed out by the RD director.
HQ AFSC, Systo HQ AFLC	23. AFSC issues a Form 56 directing the program and issues a PAD directing SM participation in engineering development.

AFSC Product Division or ALC SM	24. Prepare appropriate program management plan and submit to the approving authority. The product division normally manages development funds and the development effort. Groups A and B, data, trainer mods and support equipment are developed and tested. IOT&E is normally conducted by AFTEC or by the using command with AFTEC monitoring. Before completion of the development program, the MPA is normally requested, so that MRG review can take place immediately following IOT&E.
HQ USAF, RD Action Officer	25. When approaching the time for production initiation, the RD action officer will prepare a PMD requesting an MPA. The PMD is coordinated and signed out by the appropriate RD director. MPAs are only requested if funds will be available for production.
HQ AFLC HQ AFSC, Systo	26. HQ AFSC issues a Form 56 and AFLC issues a PAD directing MPA preparation.
ALC, SM Product Division	27. The MPA is normally prepared by the ALC SM using inputs from the product division responsible for development. The ALC CCB reviews, comments, and sends the MPA to AFLC.
Using Commands	28. Review and coordinate on the MPA.
AFLC, CCB HQ AFSC, Systo	29. The AFLC CCB reviews, comments, and sends the MPA to HQ USAF.
HQ USAF, MRG	30. The MRG reviews the development effort, MPA, IOT&E results, and PMP to determine if the mod is ready for production. NOTE: Minimum supportability criteria must have been tested and accepted by AFLC and support equipment, simulator, or training systems development complete before scheduling the MRG for approval or production funding release.

HQ USAF RD & LEY Action Officers	31. The PMD directing implementation of the mod is prepared by the USAF/RD PEM and coordinated and signed out by the RD director and AF/LEY.
HQ USAF LEY/ACB	32a. USAF/LEYM issues a program authority (PA) for mod acquisition funds. The program authority specifies the quantity of kits to be acquired in the applicable FY.
	32b. USAF/ACB issues the budget authority (BA).
	32c. PA/BA is the only document which authorized funds expenditures for this purpose. PA authorizes the program (go ahead); the BA transmits actual obligation authority.
HQ AFSC/Systo HQ AFLC	33. HQ AFSC issues a Form 56 and HQ AFLC issues a PAD directing mod implementation.
ALC/SM	34a. Prepares necessary documentation for acquisition efforts.
	34b. Normally, the SM manages the mod. If the developing product division is tasked by PD, it acquires Group B, spares, and support equipment. The SM normally acquires the trial installation if required.
	34c. Acquires necessary kits and material to accomplish mod. Ensures that support equipment, spares, trainers, etc. are acquired in time for first kit delivery.
Product Division	35. May acquire Group B when funds are transferred from the ALC. The goal is to have fully qualified Group B equipment which would enable the ALC to acquire the total mod.
ALC	36a. Manages the installation program.

	36b. Performs kit proofing.
ALC	37. Reports mod status through the G0-79 system.

APPENDIX D

LIST OF PRIMARY AIR FORCE MODIFICATION PUBLICATIONS

AFLCR/AFSCR 57-3 Class V Modification Management, 30 December 1979.

AFLCR 57-1 Modification Program Data, C1, 26 April 1976.

AFLCR 57-12 Class IV Modification Budgeting Requirements.

AFLCR 57-21 Modification Program Approval, 2 April 1979.

AFLCR 66-21 Systems and Equipment Modification Maintenance Program (G079), 3 May 1979.

AFLCR 80-4 Test and Evaluation.

AFM 172-1 Budget Operations, 3 July 1972.

AFP 172-4 The Air Force Budget, March 1978.

AFP 800-7 Integrated Logistics Support Implementation Guide for Systems and Equipment, (under revision/rewrite).

AFR 27-8 Systems and Equipment Modernization/Maintenance.

AFR 57-1 Statement of Operational Need (SON), 12 June 1979.

AFR 57-4 Modification Program Approval and Management, 2[illegible] June 1981.

AFR 65-3 Configuration Management, C1, 1 September 1974.

AFR 172-14 Full Funding of AF Procurement Programs, 6 July 1978.

AFR 800-2 Acquisition Program Management, Sup 1, 14 July 1978.

AFR 800-8 Integrated Logistics Support for Systems and Equipment.

AFR 800-14 Management of Computer Resources, Sup 1, C1, 31 March 1977.

AFSCP 800-3 A Guide for Program Management, 9 April 1976.

AFSCP 800-21 A Guide for Program Managers: Implementing Integrated Logistics Support, (under revision/rewrite).

DODD 5000.1 Major System Acquisition, 18 January 1977.

DODD 5000.2 Major System Acquisition Process, 18 January 1977.

DODD 7200.4 Full Funding of DOD Procurement Programs, 30 October 1979.

Office of Management and Budget (OMB) Circular A-109, Major System Acquisition, 5 April 1976.

OMB Circular A-109 Pamphlet. Major System Acquisition: Application of OMB Circular A-109, October 1976.

T.O. 00-5-15 Air Force Time Compliance Technical Order System (TCTO), 30 November 1978.

APPENDIX E

COMPUTER PROGRAM LISTING

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* ***** AIRCRAFT MODIFICATION SYSTEM *****
NOTE ***** CLASS IV A SAFETY DEFICIENCIES EQUATIONS *****
L     CL4A.K=CL4A.J+DT*(CL4AGR.JK-CL4ADR.JK)
N     CL4A=CL4AC
C     CL4AC=0
NOTE
NOTE
NOTE     CL4A      CLASS IV A SAFETY DEFICIENCIES
NOTE     CL4AGR    CL4A GROWTH RATE
NOTE     CL4ADR    CL4A RELEASE RATE
NOTE
NOTE
R     CL4AGR.KL=ANSD.K*WSAF.K*STAF.K*APAAF.K
A     ANSD.K=ANSDI
C     ANSDI=2.5
NOTE
NOTE
NOTE     ANSD      AVERAGE # OF SAFETY DEFICIENCIES PER PERIOD
NOTE     WSAF      WEAPON SYSTEM AGING FACTOR
NOTE     STAF      SORTIE TYPE AMPLIFICATION FACTOR
NOTE     APAAF     AIRCRAFT/PERSONNEL ACCIDENT AMPLIFICATION FACTOR
NOTE
NOTE
A     WSAF.K=TABLE(WSAFT,SLT.K,0,20,2)
T     WSAFT=10/3/1.3/1.0/1.0/1.0/1.0/1.0/1.3/3.0/10.0
A     SLT.K=TIME.K/12+ISLT
C     ISLT=4
NOTE
NOTE     SLT       SYSTEM LIFE TIME (YEARS SINCE PRODUCTION)
NOTE     ISLT      INITIAL SYSTEM LIFE TIME
NOTE
NOTE
A     STAF.K=TABLE(STAFT,SORTYP.K,1,7,2)
T     STAFT=1.0/1.03/1.06/1.09
A     SORTYP.K=PSORT1*1+PSORT3*3+PSORT5*5+PSORT7*7
C     PSORT1=.40
C     PSORT3=.50
C     PSORT5=.10
C     PSORT7=0
NOTE
NOTE
NOTE     SORTYP    SORTIE TYPE
NOTE     PSORT1    PERCENT OF VFR FLYING HOURS
NOTE     PSORT3    PERCENT OF NORMAL TRAINING SORTIES
NOTE     PSORT5    PERCENT OF REDFLAG SORTIES
NOTE     PSORT7    PERCENT OF WAR EMPLYMENT SORTIE
NOTE
NOTE
A     APAAF.K=TABLE(APAAFT,NDA.K,0,5,1)
T     APAAFT=1.0/1.0/1.04/1.05/1.05/1.05
```

```
A     NOA.K=NOAC
C     NOAC=0
NOTE
NOTE
NOTE     APAAF    AIRCRAFT/PERSONNEL ACCIDENT AMPLIFICATION FACTOR
NOTE     NOA      NUMBER OF ACCIDENTS
NOTE     NOAC     CONSTANT FOR NOA
NOTE
NOTE
R     CL4ADR.KL=CL4A.K/.5
NOTE
NOTE
NOTE     CL4ADR   CLASS IV A DEFICIENCIES RELEASE RATE
NOTE
NOTE
NOTE
NOTE ***** CLASS IV B ENGINEERING DEFICIENCIES EQUATIONS *****
NOTE
NOTE
L     CL4B.K=CL4B.J+DT*(CL4BGR.JK-CL4BDR.JK)
N     CL4B=CL4BC
C     CL4BC=0
NOTE
NOTE
NOTE     CL4B     CLASS IV B ENGINEERING DEFICIENCIES
NOTE     CL4BGR   CL4B GROWTH RATE
NOTE     CL4BDR   CL4B DEFICIENCIES RELEASE RATE
NOTE
NOTE
R     CL4BGR.KL=(RELF.K+MAINF.K)*STAF.K
A     RELF.K=TABLE(RELFT,RELDF.K,0,1,.2)
T     RELFT=20/15/12/10/8/6
A-    RELDF.K=REL.K/DREL.K*SCM.K
A     REL.K=(.8+.1*SIN(6.283*TIME.K/12))*RELAF.K
A     DREL.K=DRELC
C     DRELC=1.0
NOTE
NOTE
NOTE     RELF     RELIABILITY FACTOR
NOTE     MAINF    MAINTAINABILITY FACTOR
NOTE     STAF     SORTIE TYPE AMPLIFICATION FACTOR
NOTE     RELDF    RELIABILITY DISCREPANCY
NOTE     REL      RELIABILITY LEVEL
NOTE     DREL     DESIRED RELIABILITY LEVEL
NOTE     SCM      SYSTM COMPLEXITY MODIFIER
NOTE     DRELC    DESIRED RELIABILITY CONSTANT
NOTE
NOTE
A     SCM.K=TABLE(SCMT,SC.K,1,10,1)
T     SCMT=1.0/1.0/1.0/1.0/1.0/.99/.98/.97/.96/.95
```

```
A     SC.K=TABLE(SCT,WSCL.K,1,10,1)
T     SCT=5/5/5/5/5/5.6/7.5/8.9/9.9/10.0
A     RELAF.K=TABLE(RELAFT,SLT.K,0,20,2)
T     RELAFT=.01/.5/.75/1.0/1.0/1.0/1.0/1.0/.8/.6/.4
NOTE
NOTE
NOTE    SC      SYSTEM COMPLEXITY
NOTE    WCSL    WEAPON SYSTEM CAPABILITY LEVEL
NOTE    SLT     SYSTEM LIFE TIME
NOTE    RELAF   RELIABILITY AGING FACTOR
NOTE
NOTE
A     MAINF.K=TABLE(MAINFT,SCM.K*ESF.K*MSLF.K,0,1,.2)
T     MAINFT=20/15/12/10/8/6
A     ESF.K=TABLE(ESFT,ESLD.K,0,1,.2)
T     ESFT=.70/.85/.90/.93/.997/.99
A     ESLD.K=ESL.K/DESL.K
A     ESL.K=.8+.1*SIN(6.283*TIME.K/12)
A     DESL.K=DESLC
C     DESLC=1.0
A     MSLF.K=MSLFC
C     MSLFC=.95
NOTE
NOTE
NOTE    MAINF   MAINTAINABILITY FACTOR
NOTE    SCM     SYSTEM COMPLEXITY MODIFIER
NOTE    ESF     EQUIPMENT SUPPORT FACTOR
NOTE    MSLF    MAINTENANCE SKILL LEVEL FACTOR
NOTE    ESL     EQUIPMENT SUPPORT LEVEL
NOTE    DESL    DESIRED EQUIPMENT SUPOORT LEVEL
NOTE    ESLD    EQUIPMENT SUPPORT DISCREPANCY
NOTE    MSLFC   MAINTENANCE SKILL LEVEL CONSTANT
NOTE
NOTE
R     CL4BDR.KL=CL4B.K/.5
NOTE
NOTE
NOTE    CL4BDR  CL4B RELEASE RATE
NOTE
NOTE
NOTE
NOTE ***** CLASS IV C LOGISTICS DEFICIENCIES EQUATIONS *****
NOTE
NOTE
L     CL4C.K=CL4C.J+DT*(CL4CGR.JK-CL4CDR.JK)
N     CL4C=CL4CC
C     CL4CC=0
NOTE
NOTE
NOTE    CL4C    CLASS IV C LOGISTICS DEFICIENCIES
```

```
NOTE      CL4CGR   CL4C GROWTH RATE
NOTE      CL4CDR   CL4C RELEASE RATE
NOTE      CL4CC    INITIAL VALUE FOR CL4C
NOTE
NOTE
R      CL4CGR.KL=LSRF.K
A      LSRF.K=TABLE(LSRFT,SLF.K*SCM.K,0,1,.2)
T      LSRFT=4.0/3.5/3.0/2.5/2.0/1.5
A      SLF.K=TABLE(SLFT,SLT.K,0,20,2)
T      SLFT=.01/.40/.60/1.0/1.0/1.0/1.0/1.0/1.0/.75/.5
NOTE
NOTE
NOTE      LSRF     LOGISTICS SUPPORT REQUIREMENTS FACTOR
NOTE      SLF      SYSTEM LIFE FACTOR
NOTE      SLT      SYSTEM LIFE TIME
NOTE      SCM      SYSTEM COMPLEXITY MODIFIER
[illegible]TE
[illegible]
[illegible]4CDR.KL=CL4C.K/.5
[illegible]
[illegible]
N[illegible]DR   CL4C RELEASE RATE
NOTE
NOTE
NOTE ***** CLASS[illegible]CAPABILITY DEFICIENCIES EQUATIONS *****
NOTE
NOTE
L      CL5.K=CL5.J+DT*(CL5GR.JK-CL5DR.JK)
N      CL5=CL5C
C      CL5C=0
NOTE
NOTE
NOTE      CL5      CLASS V CAPABILITY DEFICIENCIES
NOTE      CL5GR    CL5 GROWTH RATE
NOTE      CL5DR    CL5 RELEASE RATE
NOTE      CL5C     INITIAL VALUE FOR CL5
NOTE
NOTE
R      CL5GR.KL=(CL5RQ.K+TECHAV.K/ADFAC.K)/DT
A      CL5RQ.K=TABLE(CL5RQT,WSCD.K,0,10,2)
T      CL5RQT=0/1.0/1.5/2.0/2.5/3.0
A      WSCD.K=MAX(DWSC.K-WSCL.K,0)
L      WSCL.K=WSCL.J+DT*(WSCGR.JK-WSCDR.JK)
N      WSCL=WSCLC
C      WSCLC=5
NOTE
NOTE
NOTE      CL5RQ    CLASS V REQUIREMENTS
NOTE      WSCD     WEAPON SYSTEM CAPABILITY DISCREPANCY
NOTE      DWSC     DESIRED WEAPON SYSTEM CAPABILITY
```

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NOTE     WSCL     WEAPON SYSTEM CAPABILITY LEVEL
NOTE     WSCGR    WEAPON SYSTEM CAPABILITY GROWTH RATE
NOTE     WSCDR    WEAPON SYSTEM CAPABILITY DECREASE RATE
NOTE
NOTE
A     DWSC.K=EWSCL.K*CAF.K*TAF.K
A     EWSCL.K=IEWSCL+RAMP(.02,48)
C     IEWSCL=6
A     CAF.K=1.30
A     TAF.K=MIN(1,TECHAV.K/ADFAC.K)
A     ADFAC.K=50.0
NOTE
NOTE
NOTE     EWSCL    ENEMY WEAPON SYSTEM CAPABILITY LEVEL
NOTE     CAF      CAPABILITY ADVANTAGE FACTOR
NOTE     TAF      TECHNOLOGY AVAILIABLITY FACTOR
NOTE     TECHAV   TECHNOLOGY AVAILABLE
NOTE     ADFAC    ADJUSTMENT FACTOR
NOTE
NOTE
R     WSCGR.KL=MODCOM.K(2)/FMOD.K/12.0*CL5MF.K
A     CL5MF.K=CL5MFC
C     CL5MFC=.30
R     WSCDR.KL=TECFAC.K*WSCL.K
A     TECFAC.K=TF
C     TF=.01
R     CL5DR.KL=CL5.K/.5
NOTE
NOTE
NOTE     WSCGR   WEAPON SYSTEM CAPABILITY GROWTH RATE
NOTE     MODCOM   MODIFICATION COMPLETED
NOTE     CL5MF    FRACTION OF PRODUCTION THAT ARE CL5
NOTE     TECFAC   TECHNOLOGY FACTOR
NOTE     CL5DR    CL5 MODIFICATION RATE
NOTE
NOTE
NOTE ***** TECHNOLOGY *****
NOTE
NOTE
L     TECHAV.K=TECHAV.J+DT*(TGR.JK-TDR.JK)
N     TECHAV=TECHC
C     TECHC=100
R     TGR.KL=TECHAV.K*STDF.K
A     STDF.K=SMOOTH(TDF.K,TDFD)
C     TDFD=6.0
NOTE
NOTE
NOTE     TECHAV   TECHNOLOGY AVAILABLE
NOTE     TGR      TECHNOLOGY GROWTH RATE
NOTE     TDR      TECHNOLOGY DECAY RATE
```

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NOTE     TDF      TECHNOLOGY DISCOVERY FRACTION
NOTE     STDF     SMOOTHED TECHNOLOGY DISCOVERY FRACTION
NOTE     TDFD     TECHNOLOGY DISCOVERY DELAY
NOTE
NOTE
A     TDF.K=TABHL(TDFT,SFT.K,0,1,.2)/12.0
T     TDFT=.01/.03/.07/.1/.12/.13
A     SFT.K=TABHL(SFTT,TSP.K,0,2.0,.4)
T     SFTT=.1/.15/.32/.52/.8/1.0
A     TSP.K=TP.K+DPT.K
A     TP.K=TABHL(TPT,TECHAV.K,0,100,20)
T     TPT=1/1/.8/.5/.27/.1
A     DPT.K=TABHL(DPTT,DPTD.K,-5.0,5.0,2.0)
T     DPTT=.1/.15/.2/.5/.7/.9
A     DPTD.K=WSCD.K*AMPF.K
A     AMPF.K=AMPFC
C     AMPFC=1.10
NOTE
NOTE
NOTE     SFT      SEARCH FOR TECHNOLOGY
NOTE     TSP      TOTAL SEARCH PRESSURE
NOTE     TP       TECHNOLOGY PRESSURE
NOTE     DPT      DOD PRESSURE FOR TECHNOLOGY
NOTE     DPTD     DOD PERCEIVED TECHNOLOGY DIFFERENCE
NOTE     WSCD     WEAPON SYSTEM DISCREPANCY
NOTE     AMPF     AMPLIFICATION FACTOR
NOTE
NOTE
NOTE
R     TDR.KL=TECHAV.K*TLF.K
A     TLF.K=TLFC
C     TLFC=.0167
NOTE
NOTE
NOTE     TDR      TECHNOLOGY DEACY RATE
NOTE     TLF      TECHNOLOGY LOSS FRACTION
NOTE     TLFC     TECHNOLOGY LOSS FRACTION CONSTANT
NOTE
NOTE
NOTE
NOTE ***** REQUIREMENTS SECTOR *****
NOTE
NOTE
L     NMRIR.K=NMRIR.J+DT*(MIR.JK-MAR.JK-MDAR.JK)
N     NMRIR=NMRIRC
C     NMRIRC=10.0
R     MIR.KL=(CL4A.K+CL4B.K+CL4C.K)/DT
R     MAR.KL=NMRIR.K*MAF.K/REVT
C     REVT=12.0
A     MAF.K=MAFC
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C     MAFC=.80
NOTE
NOTE
NOTE     NMRIR    NEW MODIFICATION REQUEST IN REVIEW
NOTE     MAR      NEW MODIFICATION APPROVAL RATE
NOTE     MIR      NEW MODIFICATION REQUEST INPUT RATE
NOTE     MDAR     NEW MODIFICATION REQUEST DISAPPROVAL RATE
NOTE     REVT     MODIFICATION REVIEW TIME
NOTE     MAF      MODIFICATION APPROVAL FRACTION
NOTE
NOTE
R     MDAR.KL=NMRIR.K*(1-MAF.K)/REVT
NOTE
NOTE
L     NMA.K=NMA.J+DT*(MAR.JK-MRR.JK)
N     NMA=NMAC
C     NMAC=0
R     MRR.KL=NMA.K/DT
NOTE     NMA      NEW MODIFICATION REQUEST APPROVED
NOTE     MAR      NEW MODIFICATION APRROVAL RATE
NOTE     MRR      MODIFICATION REQUIREMENT RATE
NOTE
NOTE
L     CL5IR.K=CL5IR.J+DT*(CL5R.JK-CL5AR.JK)
N     CL5IR.K=CL5IRC
C     CL5IRC=0
NOTE
NOTE
NOTE     CL5IR    CLASS V MODIFICATION REQUESTS IN REVIEW
NOTE     CL5R     CLASS V MODIFICATION REQUESTS INPUT RATE
NOTE     CL5AR    CLASS V MODIFICATION REQUESTS APPROVAL RATE
NOTE
NOTE
R     CL5R.KL=CL5.K/DT
R     CL5AR.KL=CL5IR.K/REVT5
A     REVT5.K=REVT5C
C     REVT5C=36.0
NOTE
NOTE
NOTE     CL5R     CLASS V MODIFICATION REQUESTS INPUT RATE
NOTE     CL5      CLASS V CAPABILITY DEFICIENCIES
NOTE     CL5AR    CLASS V MODIFICATION REQUESTS APPROVAL RATE
NOTE     REVT     CLASS V MODIFICATION REQUESTS REVIEW TIME
NOTE
NOTE
L     CL5A.K=CL5A.J+DT*(CL5AR.JK-CL5RR.JK)
N     CL5A=CL5AC
C     CL5AC=0
NOTE
NOTE
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NOTE     CL5A     CLASS V MODIFICATION REQUESTS APPROVED
NOTE     CL5AR    CLASS V MODIFICATION REQUESTS APPROVAL RATE
NOTE     CL5RR    CLASS V MODIFICATION REQUIREMENTS RATE
NOTE
NOTE
R     CL5RR.KL=CL5A.K/DT
NOTE
NOTE
NOTE
FOR YR=1,3
L     TMR.K(1)=TMR.J(1)+DT*(CL5RR.JK+MRR.JK+OMRR.JK+MRSR.JK)
N     TMR(YR)=TMRI(YR)
T     TMRI(*)=0/443/400
R     OMRR.KL=OGM.K/12.0
R     MRSR.KL=PULSE(TMR.K(2)/3*(1-MRRF.K)/DT,0,12)
A     MRRF.K=MHFAPR.K/MHFRIB.K
A     DUMSH1.K=SHIFTL(TMR.K,INTERV)
C     INTERV=12
NOTE
NOTE
NOTE     TMR      TOTAL MODIFICATION REQUIREMENTS
NOTE     MRR      NEW MODIFICATION REQUIRMENT RATE
NOTE     OMRR     ONGING MODIFICATION REQUIREMENT RATE
NOTE     MRSR     MODIFICATION RESUBMISSION RATE
NOTE     FMR      FUNDED MODIFICATION RATE
NOTE     MRRF     MODIFICATION REQUIREMENT REDUCTION RATE
NOTE     MHFAPR   MODIFICATION HARDWARE FUNDING APPROPRIATED (BP-1100)
NOTE     MHFRIB   MODIFICATION HARDWARE FUNDING REQUESTED IN BUDGET
NOTE     OGM      ONGING MODIFICATION REQUIRES FUNDING
NOTE     DUMSH1   DUMMY SHIFT FUNCTION
NOTE
NOTE
NOTE     THE DUMSH1 FUNCTION IS USE TO KEEP TRACK OF YEARLY MODIFICATIO
NOTE     REQUIREMENTS, BUDGET REQUESTS, ONGOING MODIFICATIONS THAT
NOTE     REQUIRE FUNDING.
NOTE
NOTE     THE INDEX YEAR (YR) IS USED TO INDICATE THE DIFFERENT FISCAL
NOTE     YEARS.  (1) IS THE CURRENT YEAR.  (2) IS THE BUDGET YEAR.
NOTE     (3) IS THE APPROPRATION YEAR.
NOTE
NOTE
L     FMOD.K=FMOD.J+DT*(FMR.JK-PULSE(FMOD.J/DT,12.0,YEARLY))
N     FMOD=FMODC
C     FMODC=65
R     FMR.KL=PULSE(TMR.K(3)*MRRF.K/DT,12,YEARLY)
NOTE
NOTE
NOTE     FMOD     FUNDED MODIFICATIONS
NOTE     FMR      FUNDED MODIFICATION RATE
NOTE     TMR      TOTAL MODIFICATION REQUIREMENTS
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NOTE     MRRF     MODIFICATION REQUIREMENT REDUCTION FACTOR
NOTE
NOTE
L      NMFUN.K=NMFUN.J+DT*(NMFR.JK-NMFRR.JK)
N      NMFUN=NMFUNC
C      NMFUNC=10.0
R      NMFR.KL=PULSE(MAX(0,FMOD.K-YOGM.K(3))/DT,.1,YEARLY)
R      NMFRR.KL=MDEV.K/12
NOTE
NOTE
NOTE     NMFUN     NEW MODIFICATIONS FUNDED
NOTE     NMFR      NEW MODIFICATIONS FUNDING RATE
NOTE     NMFRR     NEW FUNDED MODIFICATIONS REDUCTION RATE
NOTE     MDEV      MODIFICATION ENGINEERING DEVELOPMENT COMPLETED
NOTE     YOGM      YEARLY ONGOING MODIFICATIONS
NOTE     FMOD      FUNDED MODIFICATIONS
NOTE
NOTE
L      MDEV.K=MDEV.J+DT*(MDRR.JK-PULSE(MDEV.J/DT,12.0,YEARLY))
N      MDEV=MDEVC
C      MDEVC=0
R      MDRR.KL=DELAYP(MDIR.JK,DEVT.K,INID.K)
R      MDIR.KL=NMFUN.K/3.0
A      DEVT.K=NORMRN(MDEVT,STD)
C      MDEVT=18.0
C      STD=3.0
NOTE
NOTE
NOTE     MDEV      MODIFICATION ENGINEERING DEVELOPMENT COMPLETED
NOTE     MDRR      MODIFICATION DEVELOPMENT COMPLETION RATE
NOTE     MDIR      MODIFICATION DEVELOPMENT INITIATION RATE
NOTE     DEVT      MODIFICATION DEVELOPMENT TIME
NOTE     INID      MODIFICATION UNDER ENGINEERING DEVELOPMENT
NOTE     MDEVT     MEAN DEVELOPMENT TIME
NOTE     STD       STANDARD DEVIATION OF MDEVT
NOTE
NOTE
L      OGMFD.K=OGMFD.J+DT*(OMFR.JK-OMFRR.JK)
N      OGMFD=OGMFDI
C      OGMFDI=790
R      OMFR.KL=PULSE(COGM.K/DT,.75,12)
R      OMFRR.KL=MODCOM.K(1)
NOTE
NOTE
NOTE     OGMFD     ONGOING MODIFICATION FUNDED
NOTE     OMFR      ONGOING MODIFICATION DUNDED RATE
NOTE     OMFRR     ONGOING MODIFICATION FUNDED REDUCTION RATE
NOTE     COGM      CURRENT YEAR ONGOING MODIFICATIONS
NOTE     MODCOM    MODIFICATION COMPLETED
NOTE
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NOTE
L      COGM.K=COGM.J+DT*(COMFR.JK-PULSE(COGM.J/DT,0,YEARLY))
N      COGM=COGMC
C      COGMC=0
R      COMFR.KL=PULSE(YOGM.K(3)/DT,.5,YEARLY)
NOTE
NOTE
NOTE     COGM     CURRENT YEAR ONGOING MODIFICATION
NOTE     COMFR    COGM FUNDED RATE
NOTE     YOGM     YEARLY ONGOING MODIFICATIONS
NOTE
NOTE
L      OGM.K=OGM.J+DT*(OMIR.JK-OMRR.JK)
N      OGM=OGMI
C      OGMI=0
R      OMIR.KL=PULSE(YOGM.K(2)/DT,0,YEARLY)
NOTE
NOTE
L      YOGM.K(1)=YOGM.J(1)+DT*(YOMIR.JK)
N      YOGM(YR)=YOGMI(YR)
T      YOGMI(*)=0/60/50
R      YOMIR.KL=PULSE((COGM.K*.70+MDEV.K)/DT,11,YEARLY)
A      DUMSH2 "=SHIFTL(YOGM.K,INTERV)
NOTE
NOTE
NOTE     OGM      ONGOING MODIFICATIONS REQUIRE FUNDING
NOTE     YOGM     YEARLY ONGOING MODIFICATIONS INFO
NOTE     OMIR     ONGOING MODIFICATIONS INPUT RATE
NOTE     YOMIR    YEARLY ONGOING MODIFICATIONS RATE
NOTE     OMRR     ONGOING MODIFICATION REDUCTION RATE
NOTE     OGMFD    ONGOING MODIFICATION FUNDED
NOTE     MDEV     MODIFICATION ENGINEERING DEVELOPMENT COMPLETED
NOTE     DUMSH2   DUMMY SHIFT FUNCTION
NOTE
NOTE
NOTE ***** FINANCIAL SECTOR (BUDGETING) *****
NOTE
NOTE
A      MHFREQ.K=AVMC.K*TMR.K(3)
A      AVMC.K=AVMCC*(1+.06*(TIME.K/12.0))
C      AVMCC=7.0E6
NOTE
NOTE
NOTE     MHFREQ   MODIFICATION HARDWARE FUNDING REQUIREMENTS
NOTE     AVMC     AVERAGE MODIFICATION COST
NOTE     TMR      TOTAL MODIFICATION REQUIREMENTS
NOTE     AVMCC    AVERAGE MODIFICATION COST FOR FY83 & FY84
NOTE
NOTE
L      MHFRIB.K=MHFRIB.J+DT*(MHFDR.JK-PULSE(MHFRIB.J/DT,12.0,YEARLY))
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N     MHFRIB=MHFB
C     MHFB=3.1E9
R     MHFDR.KL=PULSE(MHFREQ.K/DT,12,YEARLY)
C     YEARLY=12.0
NOTE
NOTE
NOTE     MHFRIB   MODIFICATION HARDWARE FUNDING REQUESTED IN BUDGET
NOTE     MHFDR    MODIFICATION HARDWARE FUNDING DEMAND RATE
NOTE     AVMC     AVERAGE MODIFICATION COST
NOTE     TMR      TOTAL MODIFICATION REQUIREMENT
NOTE     MHFREQ   MODIFICATION HARDWARE FUNDING REQUIRMENT
NOTE
NOTE
NOTE ** O&M BUDGET **
NOTE
NOTE
A     ALCPW.K=YOGM.K(3)*AVMH.K
A     AVMH.K=AVMHC
C     AVMHC=60E3
L     MIFRIB.K=MIFRIB.J+DT*(MIFDR.JK-PULSE(MIFRIB.J/DT,12.0,YEARLY))
N     MIFRIB=MIFB
T     MIFB(*)=6.37E7/5.925E7/5.0E7
A     CPMH.K=CPMHC
C     CPMHC=15.0
R     MIFDR.KL=PULSE(ALCPW.K*CPMH.K/DT,12,YEARLY)
NOTE
NOTE
NOTE     ALCPW    AIR LOGISTIC CENTERS PLANNED WORKLOAD
NOTE     AVMH     AVERAGE MANHOURS PER MODIFICATION
NOTE     CPMH     AVERAGE COST PER MANHOUR
NOTE     MIFRIB   MODIFICATION INSTALLATION FUNDING REQUEST IN BUDGET
NOTE     MIFDR    MODIFICATION INSTALLATION FUNDING DEMAND RATE
NOTE
NOTE
L     DODRIB.K=DODRIB.J+DT*(DODDR.JK-DODRR.JK)
N     DODRIB=MHFB+MIFB
R     DODDR.KL=PULSE((MHFRIB.K+MIFRIB.K)/DT,12.25,YEARLY)
R     DODRR.KL=PULSE(DODRIB.K/DT,12.25,12)
NOTE
NOTE
NOTE     DODRIB   DOD FUNDING REQUESTED IN BUDGET
NOTE     DODDR    DOD FUNDING DEMAND RATE
NOTE     DODRR    DOD FUNDING DEMAND REDUCTION RATE
NOTE
NOTE
NOTE ** FINANCIAL SECTOR (APPROPRIATION) *****
NOTE
NOTE
L     GNP.K=GNP.J+DT*(GNPGR.JK)
N     GNP=GNPI
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C      GNPI=2858.6E9
R      GNPGR.KL=AVPI.K/12*GNP.K
A      AVPI.K=AVPIC
C      AVPIC=.109147
NOTE
NOTE
NOTE     GNP      GROSS NATIONAL PRODUCT
NOTE     GNPGR    GNP GROWTH RATE
NOTE     AVPI     AVERAGE ANNUAL PERCENTAGE INCREASE OF GNP
NOTE
NOTE
L      DODAPR.K=DODAPR.J+DT*(DODAR.JK-PULSE(DODAPR.J/DT,4.0,YEARLY))
N      DODAPR=0
R      DODAR.KL=PULSE((MIN(GNP.K*PGNPD.K*PDODM.K,DODRIB.K)/DT)
X      ,OCT,YEARLY)
C      OCT=4.0
A      PGNPD.K=TABLE(PGNPDT,GOVPOL.K,.5,1.5,.2)
T      PGNPDT=.05/.055/.06/.07/.08/.09
A      PDODM.K=PDODMC
C      PDODMC=.013
NOTE
NOTE
NOTE     DODAPR   DOD FUNDING APPROPRIATED
NOTE     DODAR    DOD FUNDING APPROPRIATEION RATE
NOTE     MIFAR    MODIFICATION INSTALLATION FUNDING APPROPRIATION RATE
NOTE     MHFAR    MODIFICATION HARDWARE FUNDING APPROPRIATION RATE
NOTE     PGNPD    PERCENT OF GNP TO DOD
NOTE     PDODM    PERCENT OF DOD FUNDING TO MODIFICATION
NOTE     GOVPOL   GOVERNMENTAL AND POLITICAL FACTOR
NOTE     DODRIB   DOD FUNDING REQUESTED IN BUDGET
NOTE
NOTE
A      GOVPOL.K=(PRESF.K+CONSF.K)*LPF.K
A      PRESF.K=PRESFC
C      PRESFC=.5
A      CONSF.K=CONSFC
C      CONSFC=.5
A      LPF.K=TABLE(LOBBY,PTHRT.K,0,1.0,.2)
T      LOBBY=1/1/1.1/1.2/1.3/1.4
A      PTHRT.K=.5+.5*SIN(6.283*TIME.K/48)
NOTE
NOTE
NOTE     PRESF    PRESIDENTIAL SUPPORT FACTOR
NOTE     CONSF    CONGRESSIONAL SUPPORT FACTOR
NOTE     LPF      LOBBYING PRESSURE FACTOR
NOTE     PTHRT    PERCEIVED THREAT OF ENEMY
NOTE
NOTE
L      MHFAPR.K=MHFAPR.J+DT*(MHFAR.JK-PULSE(MHFAPR.J/DT,4.0,YEARLY))
N      MHFAPR=MHFC
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C     MHFC=1.7E9
R     MHFAR.KL=PULSE(DODAPR.K*PDHF.K/DT,4.25,YEARLY)
A     PDHF.K=PDHFC
C     PDHFC=.75
NOTE
NOTE
L     MHFA.K=MHFA.J+DT*(MHFTR.JK-MHFOR.JK)
N     MHFA=MHFAC
C     MHFAC=4.25E8
R     MHFTR.KL=PULSE(MHFAPR.K/DT,4.5,YEARLY)
R     MHFOR.KL=KITX.K*CPKIT.K/DT
X     *CLIP(1,0,MHFA.K,KITX.K*CPKIT.K/DT)
A     CPKIT.K=MHFAPR.K/FMOD.K
NOTE
NOTE
NOTE     MHFAPR   MODIFICATION HARDWARE FUNDING APPROPRIATED
NOTE     MHFAR    MODIFICATION HARDWARE FUNDING APPROPRIATION RATE
NOTE     MHFOR    MODIFICATION HARDWARE FUNDING OBLIGATION RATE
NOTE     PDHF     PERCENT OF DOD TO MODIFICATIN HARDWARE FUNDING
NOTE     KITX     KITS IN TRANSIT TO DEPOT
NOTE     MHFA     MODIFICATION HARDWARE FUNDING AVAILABLE
NOTE     MHFTR    MHF TRANSFER RATE
NOTE     CPKIT    COST PER KIT
NOTE     FMOD     FUNDED MODIFICATIONS
NOTE
NOTE
L     MHFOB.K=MHFOB.J+DT*(MHFOR.JK-MHFPR.JK)
N     MHFOB=MHFOBC
C     MHFOBC=0
R     MHFPR.KL=DELAY3(MHFOR.JK,KST.K)*CLIP(1,0,MHFOB.K,0)
NOTE
NOTE
NOTE     MHFOB    MODIFICATION HARDWARE FUNDING OBLIGATED
NOTE     MHFOR    MODIFICATION HARDWARE OBLIGATION RATE
NOTE     MHFPR    MODIFICATION HARDWARE PAYMENT RATE
NOTE     KST      KITS SHIPMENT TIME DELAY
NOTE
NOTE
L     MIFAPR.K=MIFAPR.J+DT*(MIFAR.JK-MIFXR.JK)
N     MIFAPR=MIFA
C     MIFA=0
R     MIFAR.KL=PULSE(DODAPR.K*(1-PDHF.K)/DT,4.25,YEARLY)
R     MIFXR.KL=MIFAPR.K/12.0
NOTE
NOTE
NOTE     MIFAPR   MODIFICATION INSTALLATION FUNDING APPROPRIATED
NOTE     MIFAR    MODIFICATION INSTALLATION FUNDING APPROPRIATION RATE
NOTE     MIFXR    MODIFICATION INSTALLATION FUNDING EXPENDITURE RATE
NOTE     PDHF     PERCENT OF DOD FUNDING TO HARDWARE FUNDING
NOTE
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NOTE
NOTE
NOTE ***** PRODUCTION SECTOR *****
NOTE
NOTE
L     KITOH.K=KITOH.J+DT*(KITRR.JK-KITUR.JK)
N     KITOH=KITOHC
C     KITOHC=790.0
R     KITRR.KL=DELAYP(KITOR.JK,KST.K,KITX.K)
A     KST.K=KITC
C     KITC=3.0
R     KITOR.KL=(COGM.K/12.0)*CLIP(1,0,MHFA.K,COGM.K/12.0
X     *CPKIT.K)
R     KITUR.KL=MODIW.K/DT
NOTE
NOTE
NOTE     KITOH    LEVEL OF MODIFICATION KITS ON HAND
NOTE     KITRR    KITS RECEIVING RATE
NOTE     KITUR    KITS USE RATE
NOTE     KST      KITS SHIPMENT TIME
NOTE     KITX     KITS IN TRANSIT
NOTE     MODIW    MODIFICATION IN WORK
NOTE     COGM     CURRENT YEAR ONGOING MODIFICATIONS
NOTE     MHFA     MODIFICATION HARDWARE FUNDING AVAILABLE
NOTE     CPKIT    COST PER KIT
NOTE
NOTE
L     MODCOM.K(1)=MODCOM.J(1)+DT*(MPCR.JK)
N     MODCOM(YR)=MODC(YR)
T     MODC(*)=0/50/0
A     DUMSH7.K=SHIFTL(MODCOM.K,INTERV)
R     MPCR.KL=DELAYP(MPIR.JK,PRODT.K,MODIW.K)
A     PRODT.K=NAC.K/LOPS.K*ADJF.K
A     NAC.K=8600.0
A     ADJF.K=2866.0
NOTE
NOTE     MODCOM   MODIFICATION COMPLETED
NOTE     MPCR     MODIFICATION PRODUCTION RATE
NOTE     MPIR     MODIFICATION PRODUCTION INITIATION RATE
NOTE     PRODT    PRODUCTION DELAY TIME
NOTE     NAC      TOTAL NUMBER OF AIRCRAFT
NOTE     ADJF     ADJUSTMENT FACTOR
NOTE     LOPS     LEVEL OF PRODUCTION SPACE
NOTE     MODIW    MODIFICATION IN WORK
NOTE
NOTE
R     MPIR.KL=MIN(OGMFD.K,KITOH.K)/12.0*CAPF.K*CLIP(1,0,MIFAPR.K,0)
A     CAPF.K=MIN(PERCAP.K,FACCAP.K)
A     PERCAP.K=LOPW.K*PRDVY.K
A     PRDVY.K=PRDVYC
```

```
C     PRDVYC=1.0
A     FACCAP.K=LOPS.K
NOTE
NOTE
NOTE     MPIR     MODIFICATION PRODUCTION INITIATION RATE
NOTE     COGM     CURRENT YEAR ONGOING MODIFICATIONS
NOTE     KITOH    KITS ON HAND
NOTE     CAPF     PRODUCTION CAPACITY FACTOR
NOTE     MIFAPR   MODIFICATION INSTALLATION FUNDING APPROPRIATED
NOTE     PERCAP   PERSONNEL CAPABILITY
NOTE     PRDVY    PRODUCTIVITY OF WORKERS
NOTE     FACCAP   FACILITY CAPABILITY
NOTE     LOPW     LEVEL OF WORKERS
NOTE     LOPS     LEVEL OF PRODUCTION SPACE
NOTE
NOTE
L     LOPW.K=LOPW.J+DT*(TCR.JK-ATTR.JK)
N     LOPW=LOPWC
C     LOPWC=1.0
R     TCR.KL=DELAY3(HIR.JK,3.0)
R     ATTR.KL=LOPW.K*FATR.K
NOTE
NOTE     LOPW     LEVEL OF PRODUCTION WORKERS
NOTE     TCR      TRAINING COMPLETION RATE
NOTE     ATTR     ATTRITION RATE
NOTE     HIR      HIRING RATE
NOTE
NOTE
L     LOWIT.K=LOWIT.J+DT*(HIR.JK-TCR.JK)
N     LOWIT=LOWITC
C     LOWITC=0
R     HIR.KL=(DLOPW.K-LOPW.K)/3
A     DLOPW.K=DLOPWC
C     DLOPWC=1.0
NOTE
NOTE
NOTE     LOPW     LEVEL OF PRODUCTION WORKERS
NOTE     TCR      TRAINING COMPLETION RATE
NOTE     HIR      HIRING RATE
NOTE     LOWIT    LEVEL OF WORKER IN TRAINING
NOTE     DLOPW    DESIRED LEVEL OF PRODUCTION WORKERS
NOTE
NOTE
L     LOPS.K=LOPS.J+DT*(PSCCR.JK)
N     LOPS=LOPSC
C     LOPSC=1.0
R     PSCCR.KL=DELAYP(PSCIR.JK,CONDT.K,SUC.K)
R     PSCIR.KL=MAX(DLOPS.K-LOPS.K,0)
A     DLOPS.K=DLOPSC
C     DLOPSC=1.0
```

```
A     CONDT.K=48.0
NOTE
NOTE
NOTE    LOPS    LEVEL OF PRODUCTION SPACE
NOTE    PSCCR   PRODUCTION SPACE CONSTRUCTION COMPLETION RATE
NOTE    PSCIR   PRODUCTION SPACE CONSTRUCTION INITIATION RATE
NOTE    CONDT   CONSTRUCTION DELAY TIME
NOTE    SUC     SPACE UNDER CONSTRUCTION
NOTE
NOTE
PRINT TMR(YR),MRR,OMRR,MRSR
PRINT FMOD,NMFUN,COGM,OGMFD,YOGM(YR)
PRINT FMR,NMFR,OGM,OMIR,OMRR,OMFR,OMFRR
PRINT DODRIB,MHFRIB,MIFRIB,MRRF
PRINT DODAPR,MHFAPR,MIFAPR,MHFA
PRINT MODCOM(1),WSCL,WSCD,WSCGR
PLOT TMR(1)=T/MODCOM(1)=M/WSCL=C,WSCD=D/MHFAPR=1,MIFAPR=2
PLOT MHFA=3/GOVPOL=6,PTHRT=P/KITOH=K/MDEV=D
PLOT YOGM(1)=Y/OGMFD=O/TECHAV=+
PLOT WSCL=C,SC=S,CLSRQ=5
SPEC DT=.25/LENGTH=50/PLTPER=1/PRTPER=1
*EOR
```

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